RAILWAY TRACK

AND TRACK WORK.

By

E. E. RUSSELL TRATMAN,

A. M. Am. Soc. C. E.

Mem. Am. Ry. Eng. & M.-of-Way Assoc.

Associate Editor of "Engineering News."

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PREFACE TO THE THIRD EDITION.

The fundamental part of the great railway system of the United States is the track which forms the "rail way" and which carries the traffic. In view of its importance, and in view of the amount and quality of engineering and technical work involved in the construction and maintenance of the track, it may appear somewhat strange that the technical literature on the subject should be so limited as compared with that on other branches of railway engineering. This may be attributed largely to the fact that until within very recent years, the management of this department of railway service was considered as belonging to the grade of skilled labor rather than to that of scientific and technical training. In fact, the men who manage and control railway systems very generally fail, even at this time, to realize the importance (and especially the economic importance) of the track in its relations to the operation and business of the railway, and to questions of railway economics. The development of the position and work of the engineer of maintenance-of-way within the past few years, however, is evidence that this branch of railway engineering is coming to the front.

The book on "Track," written by Mr. Wm. B. Parsons in 1886, was practically the first book dealing with the subject from the engineering point of view, and written for the use of the engineer rather than for that of the section foreman or the "practical" roadmaster. For this reason the book had a very extensive sale among engineers, although its scope was somewhat limited. It has been out of print for over twenty years. The evident demand among engineers for a technical book on track construction and track work (or "maintenance-of-way") led the author to the preparation of "Railway Track and Track Work," with the purpose of making a comprehensive book specially adapted to engineers in the maintenance-of-way department of railway service and to young engineers intending to enter this department. The first edition was published in the autumn of 1897. Within a few months the greater part of the edition had been sold, and it was practically exhausted by the summer of 1900.

As the recognition of the track as an important feature of the railway system continued to develop, there was a continued and increasing demand for this book. This came not only from engineers but from the engineering schools, and many of these schools adopted it as a text-book in railway engineering.

The demand was met by the preparation of a second edition, which was published in 1901. This was almost entirely rewritten, as there had been many changes in both materials and methods since the preparation of the first edition. Additional chapters on signals and interlocking plant and electric railway track were added also. The increased use of signals was leading to the development of the signal department in railway service, and street and interurban electric railways were opening a new and wide field for engineers. It was felt, therefore, that these subjects ought to be included.

By 1907, the second edition had become nearly exhausted, and the writer took up the revision of the book for a new edition. This has been entirely rewritten, owing to the many changes and improvements of the past few years. Much of the older material was omitted, and new material added, especially in regard to modern developments in both methods and material. The development in the roadway or maintenance-of-way department as a separate engineering department in the railway organization also influenced the work on the new edition. This department is now, in many cases, more or less independent of the engineering department, whose work relates mainly to general construction and improvement. Many new illustrations have been made, and an appendix presents statistics of the details of standard track construction on a large number of American railways. An extensive index is included, with a separate index of railways whose practice is mentioned. There is also another separate index of engineers, inventors, and authorities mentioned or quoted.

A special feature of this book is that it includes not only the general principles underlying track design and maintenance, and the systems of practice which are everywhere applicable. It includes also numerous details as to equipment, material, appliances and methods as used by individual railways and in different sections of the country. It is believed that mere general statements as to construction and methods of work leave very much to be desired both by the beginner or student, and by the engineer actually engaged in maintenance-of-way work. It has been the author's special aim, therefore, to present descriptions in detail of various appliances and methods representing actual practice. Their good and bad features are presented, as well as the reasons for their use. The aim has been, however, to make the work representative, rather than to make it diffuse. This comprehensive but representative treatment is a particular characteristic of the style of the book, and has met with very considerable commendation, showing that it meets a definite need. The scope of the book is large, as may be seen by a glance at the table of contents. The various subjects included are treated not merely in a descriptive manner but also in a critical manner.

It would be impracticable to mention each and every engineer, railway officer, or manufacturer of railway material who has furnished information for use in the revision of the book, but the author takes the opportunity to extend his thanks for all information furnished. He also desires to express his appreciation of all criticisms, corrections and commendations which have been sent to him.

E. E. RUSSELL TRATMAN.

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PART I.—TRACK.

CHAPTER I.—INTRODUCTION.

The railway system of the United States now aggregates about 230,000 miles of railway, with 330,000 miles of track (including sidings and yards). The maintenance of 230,000 miles of railway in proper condition for safely and efficiently carrying the traffic is an important work; and to control this work with efficiency and economy requires skill, judgment and executive ability. A glance at the table of contents of this book will give a good idea of the variety of items included in track and track equipment, and also an idea of the variety of work required for maintaining the track in condition. This work is classed under the term "maintenance-of-way." In addition to the varied material and work involved, account must be taken of the care required in devising both the system of construction and the methods of work best adapted to the proper and economical conduct of the work under the various conditions of construction and operation which exist on different railways.

The track upon which the traffic has to be carried is one of the essential and most important features of a railway, but its importance has been to a large extent lost sight of, or subordinated to other matters. Certainly the following facts in regard to track and track work (or maintenance-of-way) are not realized as clearly as they should be by railway officers: 1, The importance of the track and track work in their relation to the operation and business of the railway; 2, The large proportion of the operating expenses which is represented by the expenditures on track maintenance; 3, The economic importance of good track for railways carrying fast and heavy trains and a dense traffic.

There is a growing recognition of the fact that the management of the track work and the track forces on important railways should be in the hands of men of engineering training; men who understand not only the practical work but also the principles upon which the work is based. They must be competent to deal with the problems arising under modern conditions, where speed of trains, a high grade of track construction and maintenance, and a close economy in maintenance work are involved.

There has been a tendency for managements to disregard recommendations from and requisitions for the track department. Even on roads appropriating large sums for general improvements (such as realinement and grade reductions), there is often a certain hesitation in regard to expenditures on track improvement. The engineers can show and the transportation officers can realize the direct economy in operation resulting from expenditures for general

improvements. But unless the maintenance-of-way is in the hands of engineers, the relative advantages and direct economies of heavier rails, better joints, treated ties, better ballast and improved appliances are not apt to be so fully presented or understood.

Financial conditions sometimes compel railways to conduct their operations with very limited means. There is then opportunity for the exercise of skill and judgment in distributing work and money to the best advantage, for these conditions are rarely an excuse for defective and neglected track. On the other hand, some railways in better financial circumstances appear to consider that maintenance expenses should be permanently low. They overlook the necessity of renewals on account of depreciation and for improving the track as the traffic increases. Therefore, while they appropriate large sums for new engines and cars, handsome passenger trains, new stations, etc., and for methods of developing traffic and business, they are not willing to authorize liberal expenses for track and roadway improvement.

It should be recognized that the poorer the track, in relation to the traffic, the greater will be the expenses for maintenance and renewals, owing to the inability of the track to sustain the weights and shocks to which it is subjected. The importance of the maintenance department is perhaps most thoroughly understood by the engineers of that department on a road where the conditions include light track, fast trains, heavy traffic, small appropriations, and frequent admonitions to keep down the expenses. Many railways, of course, are managed on a more enlightened policy, which takes into account two fundamental principles: 1, The necessity of renewals and improvement to compensate for normal wear and depreciation; 2, The necessity of general improvement to maintain the track in proper relation to the increasing traffic and loads which are imposed upon it.

It must be admitted, however, that in some respects the administration of the track or maintenance-of-way department in the past has left much to be desired. The matter of ties affords an example. These are purchased and used in large quantities, and represent an important item in the expenses; yet very few railways have complete or reliable records as to the life, cost and relative economy of the various kinds. This may appear strange from two points of view: First, The importance of the ties as a part of the track structure, and Second, The vigorous way in which attention has been called to the economics of the tie-supply question during recent years. It seems that these features are still very imperfectly recognized, and very imperfectly impressed upon the railway management. These are matters which the maintenance-of-way department should have taken in hand long ago, and in a systematic and energetic manner. At the present time, little more than a beginning has been made in this direction.

The fastenings of the rails to the ties continue to constitute a decidedly weak and inefficient feature of the track structure of American railways. However well the spike may have been, and still may be, adapted to light track with light traffic, it is quite inadequate for modern conditions of railway service. Probably few outside of the maintenance-of-way department realize the amount of work required in redriving and renewing spikes to keep a main track in reasonably good condition under even moderate traffic; or the amount of damage thus done to the ties, and the consequent increased cost and work represented by the tie renewals. The mileage of track on which any form of improved

fastening is used is infinitesimal, even when compared with the mileage of busy main tracks only.

An objection to American practice which has been made frequently by European railway engineers is the extensive use of rails of comparatively light weight (in relation to the loads carried). It must be remembered, however, that the rail is only one part of the track structure, and that it is not (as is often assumed) a girder resting upon rigid supports. The whole track deflects under load by the compression of the ballast and roadbed, independently of the deflection of the rails between the ties. Consequently a 70-lb. or 75-lb. rail supported by 18 to 20 ties may form a track smoother and more substantial than one with 80-lb. or 90-lb. rails on 12 or 15 ties to each rail. It follows, also, that American track with 80-lb. to 100-lb. rails supported by 18 or 20 ties to the rail length, will be more smooth and substantial than foreign track with rails of the same weight supported by only 10 or 12 ties. This is a point not infrequently overlooked. Indeed, some engineers have erroneously reasoned that in introducing heavier rails the number of ties can be reduced without affecting the quality or condition of the track.

Railway track as a unit, or a complete structure, designed and built for the purpose of carrying certain loads in the form of moving trains, has received very little attention. Each part is considered separately, and not in its relation to the other parts of the structure. Thus, a certain weight of rail may be adopted arbitrarily without regard to such related factors as the size and spacing of ties, the depth and quality of ballast, or the bearing area of the ballast and roadbed. In renewals with heavier rails on account of increased loads, the rails are not infrequently laid in track which receives little other improvement beyond a little dressing of the surface. There have been numerous investigations as to rails, ties, joints, the holding power of spikes, etc. But the track as a single structure or unit has been mainly overlooked. One of the most thorough investigations in which this unit character of the track has been considered, is that made in France by Mr. Cuenot, of the Paris, Lyons & Mediterranean Ry. The increase in train speeds on that road made necessary a close study of the track to ascertain the stresses to which it is subject, and to determine how its strength could be increased to withstand these stresses. Special apparatus was designed to measure some of the stresses.

The results of the investigations have been published by Mr. Cuenot, and he states that the various deformations of track are caused by two principal movements: transverse and vertical. These account for vertical and horizontal displacement of the rails, variations of gage, creeping of rails, loosening or drawing of spikes, and distortions at joints. The transverse movement is due to the fact that the tie does not sink uniformly throughout its length in the ballast as it receives its load. The top of a tie more than 7 ft. 6 ins. long is concave at each end when loaded (causing an inward inclination of the rails), with a slight convexity at the middle. A tie less than 6 ft. 10½ ins. long is convex for its entire length, causing an outward inclination of the rails. He considered that ties 7 ft. to 7 ft. 3 ins. long would be depressed uniformly and thus remain horizontal. It is not at all likely that railways will introduce ties shorter than the usual lengths of 8 ft. and 8 ft. 6 ins. The rigidity, however, may be increased by making them deeper. This would be a most important improvement. It would not only avoid disturbance of track and ballast caused by the flexibility of the ties, but would give also a

more uniform distribution of the load upon the ballast. In relation to the bearing area of the tie, however, it is noted that the ballast should be so tamped as to give an exceptionally firm bearing for not more than 15 ins. on each side of the rail. Then the main support will be upon this portion of the ballast, and not upon that under the middle or ends of the ties. The reason for this is that pressure transmitted through the tie (as a rigid elastic mass) to the ballast and subgrade (as an elastic body) diminishes very rapidly as the distance from the line of loading increases. Rail deflection at joints is also a serious matter, and has been found to reach nearly ¼-in., when the yielding of the tie would not exceed ⅛-in.

The following conclusions were deduced by Mr. Cuenot as to necessary improvements for track carrying fast and heavy traffic; the use of heavy rails, steel tie-plates, and screw spikes is taken for granted: (1) The ties should be two or three times more rigid than those now in use (this excludes the use of steel ties of trough section); (2) The three-tie type of joint should be used, with ties 12 ins. apart; (3) The tie-plates should have outside ribs to give a bearing to the back part of the head of the screw spike; (4) By supporting the joints and increasing the rigidity of the ties, the resistance to traction would be materially reduced, while trains could be run at higher speeds without any reduction in comfort or safety.

The tamping of the ballast under the ties so as to give a firm and uniform support is one of the most important features in the work of track maintenance. It is, however, manifestly impossible to attain any approach to ideal conditions of a uniform support even with the most experienced labor. With about 2,500 independent rail supports (the ties) in a mile of track, or even with 18 to 20 supports to a rail length of track, the conditions of labor and material render it impossible to obtain uniformity in the support afforded by the ballast as tamped under individual ties. In theory, each tie is a rigid pier carrying the continuous girder of the rail. In practice, ties are supports of varying and unknown stability, yielding unequally under pressure. This increases the span of the girder (or rail), and the rail may be subjected to stresses which it is not designed or intended to carry. Any increase in its deflections, due to the yielding of its supports, is a decrease in the quality of the track considered as a structure for the purpose of carrying rolling loads. The extent of the yielding of the ties tends to increase automatically by the compression, movement or disintegration of the ballast which forms the foundation material. This condition leads us to the consideration of another important matter regarding the relation of track to traffic.

The track should be designed with a view to the loads which it is to carry, but it is safe to say that no actual track is thus designed. The matters which are ignored include the loads and their distribution, the stresses in the rails, the bearing area afforded by the ties and ballast, and the relation of bearing area to weight of train and stresses in track. This matter has been considered by Mr. O. E. Selby ("Engineering News," February 14, 1907). He states that the fiber stresses in Bessemer steel rails should not exceed 15,000 lbs. But in existing track with an axle load of 50,000 lbs. and 100% allowance for impact, the extreme fiber stress may reach 18,750 lbs. in an 80-lb. rail having a section modulus of 10. The limiting bearing pressures should be 400 lbs. per sq. in. on oak ties, 4 tons per sq. ft. on gravel or broken stone not well confined, and 1 to 1½ tons per sq. ft. on clay foundation (subgrade) sub-

ject to frost. For track carrying axle loads of 60,000 lbs. he proposed a specially heavy track of the ordinary type. The rails would be 7 or 8 ins. high, weighing 115 lbs per yd. (with a section modulus of 20); they would be laid upon ties 7×9 ins., 8½ ft. long, spaced 20 ins. c. to c. There would be 12 ins. of stone ballast under the ties, and 12 ins. of gravel ballast beneath the stone. The ballast would be 10½ ft. wide at the top of ties, with side slopes of 1 on 2, and a bottom width of 21 ft. This arrangement would give a load (including impact) of 1 ton per linear inch of roadbed, or 1.2 tons per sq. ft. of roadbed (distributed over a width of 10 ft.). He estimated that such a track would reduce maintenance expenses 50 per cent.

Improved or special construction at high cost might be really economical for busy lines with heavy traffic, where the cost of maintenance-of-way is high. It is of some importance to note that improvements in railway track have been confined entirely to the detail parts of a track structure which is of the same general type as that of 50 years ago. A few, very few, experiments with radical innovations or new designs have been made on a small scale, but certainly with no idea of following them up in practice. There is indeed no probability of the introduction of any new type of track.

A weak point in the present type of track is the carrying of the rails on intermittent supports which have no uniformity of bearing in the ballast. Two combinations of continuous steel longitudinal bearings with intermittent rail supports have been suggested to eliminate this feature. The plan proposed by Mr. J. W. Schaub, and shown in Fig. 1, is to place wide-flanged 10-in.

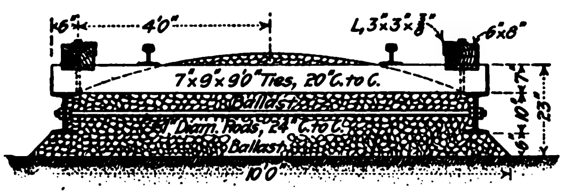


Fig. 1.—Proposed Track Construction with the Ties Supported by Longitudinal I-Beams.

I-beams under the ends of the ties. The beams would be embedded in 16 ins. of ballast and connected by tie rods. Individual ties could not get loose or low, and the load upon them would be distributed to the ballast by the I-beams. In surfacing, these beams would be raised by jacks and tamped, instead of tamping individual ties. A more elaborate plan, designed by Mr. G. Lindenthal, is shown in Fig. 2. In a modified form in use for about 1,000 ft.

Fig. 2.—Proposed Track Construction with Steel Longitudinals Carrying Steel Blocks or Chairs for the Rails.

in a freight track on the Pennsylvania Ry., there are two built-up longitudinals of double channel section, composed of two 8×3-in. Z-bars (with bottom flanges outward), each having a 7×3-in. bulb angle riveted to the

outside of the top of the web. These carry oak blocks 6×8×26 ins., spaced 2 ft. c. to c. At intervals of 6 ft. there are ties of the same size, 7 ft. 2 ins. long, to maintain the gage. At each rail joint, also, there are two shoulder ties 36¾ ins. c. to c., with a block under the joint. The rails rest on steel tie-plates and are secured by screw spikes. The blocks are secured to the longitudinals by hook bolts. The original design (Fig. 2) provided for longitudinals composed each of a pair of special bulb angles 6×8 ins., with vertical diaphragm plates between them; also cast-steel chairs for the rails and steel tie-bars. No such angles have yet been rolled, and the chairs are too costly for experiment. Some cast-iron chairs proved unsatisfactory and were replaced by the wooden blocks and ties. A track somewhat similar to this, but with the longitudinals embedded in concrete, has been used in the Philadelphia underground railway. This is described elsewhere.

The use of a concrete roadbed has been suggested many times, mainly in two different ways: (1) Separate lines of concrete beams or longitudinals; (2) A concrete floor or slab. The longitudinals would be laid upon a bed of crushed stone or clean gravel, and bedded in earth as a protection against frost penetrating below them. The rails might be laid upon the longitudinals, and connected by tie-rods. Or they might be laid upon longitudinal I-beams anchored to the concrete and connected by transverse beams. This latter system, with 10-in. wide-flanged I-beams anchored to longitudinals 16 ins. deep and carrying rails of bridge section, has been estimated to cost $25,000 per mile of single track. Any necessary surfacing would be effected by raising the longitudinals with jacks. It may be mentioned that concrete longitudinals have been used in the inclined shaft of a copper mine in Michigan. A plan proposed by Mr. J. W. Schaub for a concrete floor construction, provides a continuous reinforced-concrete slab 10 ft. 2 ins. wide, 8 ins. thick at the sides and 14 ins. at the middle. Longitudinal timbers rest upon the thinner parts and against the sides of the thicker part, and are held in place by long horizontal bolts passing through both timbers. Ordinary rails would be laid on steel tie-plates, and secured to the longitudinals by screw spikes. The slab would rest upon an 18-in. bed of rubble concrete. The cost is estimated at $14,000 per mile of single track, as against $6,000 for the ordinary type of track (the cost of rails being omitted in each case). The Michigan Central Ry. has experimented with a track system for its Detroit tunnel in which the concrete floor has a central drain with transverse recesses on each side to receive creosoted blocks for the rails. Tunnels and underground railways, which have a concrete floor as a part of the construction, do not afford a criterion for ordinary railway track.

In experiments with new track material or appliances, special care should be taken to have the new appliances installed under exactly the same conditions as the older ones. The trials should also cover a considerable length of track if any definite results are to be expected. The Prussian State Railways have built a special track for experiments with different kinds of ties, ballast and rail joints, and to show the wear of rails on curves and tangents. It forms an oval with tangents 820 ft. long and end curves of 650 ft. radius, making a length of about a mile. The curves have the gage widened 0.095-in.; they have a superelevation of 4.92 ins., with different lengths of run-off at each end. On this track will run 58-ton electric cars, each having six-wheel trucks and four motors. The train will be run continuously, without a crew.

During recent years there has been a tendency to strengthen the track on main lines, in order to meet the conditions of increased engine loads and increased traffic. Tables of the standards for main-track construction on a number of railways have been compiled by the author, and form an appendix to this book. It must be borne in mind, however, that the extent to which the standards are in actual use is an unknown and extremely variable quantity. They are naturally confined to the divisions having the densest traffic, and it is to be noted that (with the exception of a few short roads) they are not used on all parts of the line which carry heavy equipment or fast trains. A railway having several hundreds of miles of track will include, as a rule, various kinds of track construction and traffic conditions. It may have but a small proportion of its length laid with what is nominally its "standard" track. The quality of the maintenance and general condition of the track is likely to vary in equal ratio with the character of construction. Thus the "maximum" freight train, the "fast-freight" train, and the heavy high-speed passenger train, with their locomotives heavy in axle loads and total weight, may run for considerable parts of their journeys upon track which is not properly adapted for such service. This results in wear and tear of the equipment, and the track is in turn liable to suffer excessive injury by the character of the traffic which it has to carry. Such conditions involve not only a high cost of maintenance, but a low factor of safety. It is to be feared that in general this latter feature is overlooked.

A classification of track on the basis of traffic carried has been adopted by the American Railway Engineering Association. This is as follows, but is really a classification of railways rather than of track: A, All double-track divisions, and single-track divisions having a freight-car mileage of 150,000 per mile per year, or a passenger-car mileage of 10,000 per mile per year, and a maximum passenger-train speed of 50 miles per hour. B, Single-track divisions having a freight-car mileage of 50,000 or a freight-car mileage of 5,000 per mile per year, and a maximum passenger-train speed of 40 miles per hour. C, All lines or divisions not meeting the requirements for Classes A or B.

The relation of the track structure to the traffic which it is to carry is overlooked very generally. For new lines, the weight of rails, size and spacing of ties, depth and character of ballast, etc., are very rarely adopted on any basis of traffic conditions. If heavier locomotives and heavier, faster and more numerous trains become necessary to handle the business of an existing road, little consideration is given to the ability of the track to carry the increased loads and traffic with safety and economy. Many engineers and roadmasters have experienced the increasing difficulty in maintaining track which has not been improved or strengthened to correspond with the heavier locomotives, higher speeds and increased train service of recent years.

With a track that is light in relation to the loads imposed upon it, there is an increase in expense for maintenance. Rails are more rapidly worn and more liable to break, rail joints become low and loose, ties are damaged, soft ballast is crushed, frogs and switches are battered, and the track may be shifted bodily in the ballast. Apart from the increase in renewals due to wear, there is a decided increase in the various items of work required to maintain the track in line and surface. All this is due to the disturbance and dislocation caused by the heavier conditions of traffic and the lack of proper relation between the track structure and the traffic. It is a very evident fact that in general

the track has not been strengthened or improved in due proportion to the increase in service imposed upon it by (1) the heavier loads, (2) the higher speeds, and (3) the denser traffic. Train equipment is adopted and train speeds are arranged without much consideration of the character of the track construction, the cost of maintenance-of-way or the factor of safety involved. That these matters should be considered admits of no dispute.

The lack of proper relation between track and traffic is evidence of the necessity of improvement of the track. But it does not constitute any argument against the development of transportation or operating methods. The business of the railway is to carry traffic, and the methods of operation will be governed by the requirements of that business. It is useless for the maintenance-of-way department to complain about the effects of increased loads and speeds upon the track, with any view to a modification in traffic conditions. On the contrary, the track must be made to fit the traffic conditions, since it is the traffic which makes the business of the railway and earns the revenue. It is one duty of the engineer to present to the executive officers the desirability of improving the track as the traffic conditions become more severe. He should be able to show very clearly that there must be a certain factor of safety, and that better efficiency and higher economy of the railway service as a whole might be obtained by building or improving the track with due regard to its proper relations to the locomotive equipment and the traffic conditions. In any case, it is the work and duty of the engineer and the roadmaster to maintain the track in the best possible condition and the best possible relation to the traffic which it must carry. This subject has been discussed in some detail in "Engineering News" of Sept. 13, 1906. Also in two papers read by the author before the New York Railway Club: "The Relations of Track to Traffic" (1896), and "Maximum Trains; their Relations to Track, Motive Power and Traffic" (1902).

Improvements for the purpose of getting the traffic over the road with the least possible delay and with a greater degree of safety are now largely needed. These include the track construction, the double-track and passing-siding facilities, the yard and terminal facilities, coaling and water-station equipment, block signals along the open line, and interlocking plants at such points as crossings, junctions, passing sidings and yard entrances. The important relation which double-track and yard and terminal facilities bear to the prompt movement and efficient handling of railway freight traffic has been forced upon the attention of railways by several periods of traffic congestion during recent years. The double-tracking of main lines to relieve this congestion is of perhaps greater importance than the building of new branches and extensions. The new lines bring more traffic upon the main lines and thus serve to increase the congestion. As to the yards, the delay of a car in any one division yard may be easily from 10 to 20 hours. This may be increased enormously under adverse conditions, and especially where the car has to be transferred from one yard to another at a terminal point. The cumulative detention to a car making a long trip may thus amount to several days. It may be reduced in many cases by improvements in the design of the yard and its connections, as well as in the methods of yard operation. These important matters of track and yard facilities were discussed by the author in "Engineering News" of Sept. 14, 1905, and April 4, 1907.

The results obtained from expenditures on track are in very many cases

unsatisfactory from the practical and the economic standpoint, owing to a failure to realize the governing conditions. In hundreds of cases, money is spent over and over again upon the same stretch of track without any permanent improvement being obtained. This work is required to repair the track and maintain it in a normal condition. It may be made necessary by defects in material or construction, or by an increase in loads and traffic. In many such cases it would be a matter of evident economy to take up the problem in earnest, discover the proper remedy, and carry out some permanent work. But this would mean a definite and large expenditure, and the company is likely to consider that this cannot be afforded. As a result, the continual but unnoticed drain of expense in "maintenance" and temporary repairs is allowed to continue. The principle should be more clearly and generally understood that large expenditures on radical or permanent improvements may effect important economies in maintenance and in other departments of the service. The economics of track construction and maintenance-of-way, and their relation to the economics of railway operation and management, need to be impressed upon those who control the finances. But it is to be feared that these men are rarely interested in the science of the economics of railway transportation.

The proportion which the charges for maintenance of way and structures bear to the total operating expenses of American railways is usually high, as shown in Table No. 1. This is largely due to the fact that a majority of the roads have been built with regard to immediate cheapness and rapidity of construction rather than to ultimate economy in operation. The conditions under which the railways have been built (often in advance of the pros-

TABLE NO. 1.—RAILWAY MAINTENANCE-OF-WAY EXPENSES.

Railways.	Miles.	Operating Exp. to Gross Earnings.	—Maintenance-of-Way— Per Mile.	Percentage of Oper. Exp.	Percentage of M. of W. and St.	Maint. of W. and St. per Mile.	—Percent. of Op. Exp.— M. of W. and Struc.	Maint. of Equipment.	Conducting Trans.
		per ct.	$	per ct.	per ct.	$	per ct.	per ct.	per ct.
N. Y., N. H. & H.	2,060	68.07	1,130	10	62	2,660	14.4	14.9	66.8
N. Y. Cen.	3,780	77.06	2,570	13	78	3,297	16.4	19.6	60.7
Penna.	3,858	72.57	3,504	12	67	5,253	16.9	26.5	53.4
B. & O.	4,462	66.73	1,863	15	78	2,363	19.2	24.5	53.5
D., L. & W.	957	57.80	3,289	15	63	5,198	23.1	17.3	57.0
Le. Val.	1,440	61.31	1,700	11	78	2,500	14.5	27.5	55.0
Ph. & Read.	1,000	60.00	2,983	12	83	3,606	14.0	30.8	52.4
Erie	2,333	70.79	1,748	12	71	2,180	13.3	21.3	47.4
L. S. & M. So.	1,520	65.72	3,483	18	84	4,163	21.4	20.4	55.3
C., C., C. & St. L.	1,982	76.13	1,470	14	85	1,732	17.0	29.0	53.0
Southern	7,547	78.89	790	13	62	1,015	17.1	21.4	53.6
Cen. of Ga.	1,913	79.50	600	12	73	825	16.4	23.4	50.8
L. & N.	4,340	74.14	1,150	14	62	1,860	22.5	24.3	50.0
Ill. Cen.	4,377	66.86	1,123	13	72	1,565	18.5	25.3	53.4
Hock. Val.	644	64.87	821	13	86	1,069	18.0	33.0	45.8
T., P. & West.	231	81.38	915	20	75	1,163	25.4	26.2	40.7
So. Ind.	246	59.00	663	17	80	831	21.0	22.0	50.0
Cin. So.	336	80.23	3,000	14	77	3,892	18.6	24.1	50.3
C. & O.	1,832	64.50	1,177	13	70	1,686	18.5	28.3	50.7
N. & W.	1,877	62.62	1,465	14	71	2,077	20.0	26.8	52.0
Ch. & A.	970	65.53	1,157	13	78	1,473	17.8	20.0	58.1
Ch. & N. W.	7,623	65.30	882	15	75	1,168	19.9	19.4	58.0
Ch., M. & St. P.	7,186	62.63	641	12	70	828	17.0	16.0	56.7
Wabash	2,514	71.10	870	12	80	1,093	14.1	20.1	62.3
Mo. Pac.	6,375	66.80	769	15	83	926	18.1	21.5	54.1
St. L. S. W.	1,454	68.19	...	..	..	1,308	23.0	18.5	50.5
Den. & R. G.	2,552	61.90	731	14	79	920	17.7	22.2	56.0
A., T. & S. F.	9,350	62.84	1,239	20	76	1,648	26.0	20.0	50.0
So. Pac.	9,694	64.21	1,262	17	77	1,362	21.7	20.4	53.3
Un. Pac.	5,916	53.36	1,318	20	78	1,695	24.9	19.5	55.0
Max.	...	81.36	3,504	10	86	5,253	26.0	33.0	66.8
Min.	...	53.36	600	20	62	828	13.3	14.9	40.7
Ave.	...	67.66	2,052	15	74	3,040	19.6	23.9	53.7

pective traffic) have, on the whole, warranted the carrying out of the work on this principle. In too many cases, however, the original style of construction has been allowed to remain unaltered and unimproved long after it has been outgrown by the traffic. The result of this is that such roads have to sustain a heavy continual charge for maintenance. These conditions and their relation to operating conditions are now being given much greater consideration, due largely to the necessity of handling more traffic and with greater economy. Within the past few years many roads have spent enormous sums of money in general improvements, such as reducing grades and curves, improving the location, double tracking, improving yard and terminal arrangements, and replacing trestles and light structures with solid embankments and more permanent structures.

The operating expenses of the railway system of the United States for the year ending June 30, 1906, amounted to 66.08% of the gross earnings, and 72.26% of the total expenditures. The expenses for maintenance of way and structures (exclusive of general improvements) amounted to 20.28% of the operating expenses. Analyzing the details of these figures, it is found that repairs to roadway represent about 10.73% of the entire operating expenses; rail renewals and tie renewals represent 1.43% and 2.51% respectively. A consideration of the fact that the maintenance work on track and structures absorbs some 21% of the operating expenses, and the further fact that half of this is for ordinary every-day roadway repair work (exclusive of rail and tie renewals), will show the importance of the relation which the maintenance-of-way department bears to the financial affairs of the railway company. It becomes evident then that greater importance should be attached to the proper organization and accounting of this department. The distribution of expenses is given in Table A.

TABLE A.—DISTRIBUTION OF RAILWAY EXPENSES.

Distribution of Total Expenses.	Per Cent of Op. Exp.	Per Cent of Total Exp.	Distribution of Exp. for Main. of Way and St.	Per Cent. of Op. Exp.
Maint. of way and struc....	20.28	14.66	Repairs of roadway........	10.73
Maint. of equip...........	21.38	15.44	Renewals of rails..........	1.43
Conduct. transp...........	54.41	39.32	Renewals of ties...........	2.51
General and unclass.......	3.93	2.84	Rep. and renewal:	....
			Bridges and culverts.....	2.21
Total op. expenses....	100.00	72.25	Fences, road crossings, signs and cattleguards..	0.41
Fixed charges.........	......	27.74	Buildings and fixtures....	2.30
Total expenses........	......	100.00	Docks and wharves......	0.24
			Telegraph...............	0.18
			Other expenses............	0.29
			Total................	20.30

This summary for the railway system as a whole gives, of course, but a general average of the distribution of expenses. The relations of the maintenance-of-way and operating expenses on a number of individual railways are shown in Table No. 1, which has been compiled from official reports. In many statistics of this kind, the figures are given simply for maintenance of way and structures. But as the expenditures on structures vary widely, according to the number and character of the structures, these combined expenses do not afford a basis for comparison of maintenance-of-way expenses proper. In this table, therefore, the author has separated these latter expenses. The figures of maintenance-of-way in the table cover the following items: repairs to roadway, renewals of rails and ties, and repairs and renewals of fences, road crossings, cattleguards and signs. The cost for these items alone averages from $600 to $3,500 per mile of road per year, and it represents from 10 to

20% of the operating expenses. The general classification of "maintenance of way and structures" includes the above items and also repairs and renewals to bridges, buildings, wharves, docks, signals, etc. The cost for this general classification averages from $830 to $5,250 per mile of road per year, and from 13 to 26% of the operating expenses. The "maintenance-of-way" items, noted above, represent from 62 to 86% of the expenses for maintenance of way and structures. The analysis of railway maintenance expenses was discussed in "Engineering News" of July 27, 1905, and some results are shown in Table B.

TABLE B.—RAILWAY MAINTENANCE-OF-WAY EXPENSES.

Railways.	Expenses of Maint. of Way and Struc.			Expenses of Maint.-of-Way.		
	Way.	Bges. and Culv.	Bldgs. and Docks.	Roadway and Track.	Rail Renewals.	Tie Renewals.
	%	%	%	%	%	%
Boston & Maine	76	7	12	74	4	17
Erie	70	9	14	44	11	14
Lehigh Valley	71	8	14	63	8	25
Del., Lack. & West	58	14	25	67	10	16
New York Central	80	5	13	67	10	18
Norfolk & Western	80	9	10	40	20	15
Chesapeake & Ohio	78	6	14	65	13	16
C., C., C. & St. L.	77	8	8	58	6	20
Wabash	72	14	12	73	7	15
Louis. & Nash	65	11	7	55	10	16
Illinois Central	78	9	10	76	6	15
Chicago & N. W	74	9	10	65	10	19
C., M. & St. P	77	13	9	70	10	15
A., T. & S. F	75	13	10	65	8	18
Union Pac	73	11	13	62	13	24
Denver & R. G	82	8	7	60	9	14
Maximum	82	14	25	74	20	25
Minimum	58	7	7	40	4	14

The cost of the several features of railway track construction will necessarily vary within extremely wide limits, due to the character of construction and country, and the market rates for labor and material. In several states some attempt has been made to put a valuation on the railways, on the basis of cost of construction at the present time. Table C shows some of the items of the valuations in Wisconsin and Michigan, and also of a similar valuation made by the Great Northern Ry.

TABLE C.—ESTIMATES OF COST OF RAILWAY TRACK.

	Wisconsin		Michigan		
	Per Cent. of Total Cost.	Cost per Mile. $	Per cent. of Total Cost.	Cost per Mile. $	Gt. N. Ry. Cost per Mile. $
Rails	12.91	3,773	14.05	3,674	4,680
Ties and switch ties	4.95	1,529	5.46	1,426	2,820
Fastenings	2.00	617	1.88	492	1,110
Frogs, switches and crossings	0.48	151	0.72	188	135
Ballast	2.55	788	1.83	476	1,585
Tracklaying and surfacing	1.45	447	3.21	839	1,055
Fencing	0.73	225	1.36	353	115
Road cross., cattleguards and signs	0.17	52	0.30	78	290
Interlocking and signals	0.17	52	0.25	64	60
Stations	1.54	476	2.01	526	495
Water and coal stations	0.69	180	0.51	132	390
Bridges, trestles and culverts	7.67	2,372	3.93	1,027	2,705

Throughout this book there are given numerous rules and instructions as to methods of work, but it must be distinctly understood that rules cannot be made universally applicable and therefore must not be followed blindly. Owing to varying conditions of track, traffic, topography, labor, etc., a method which may be the best practice in one case may be entirely unsuitable in another. Therefore every man must exercise his own judgment. He should not adopt a method simply because he finds it has been used; nor should he assume that a method is wrong simply because it could not be applied to advantage

on his own road or division. Engineers and roadmasters should comprehend the principles underlying their work, should be familiar with the general rules of practice outside their own particular sphere, and should take into consideration the actual conditions under which their work is to be done. Upon this basis they should devise or adopt such methods or materials as will give the best and most economical results under these governing conditions.

In concluding this introductory chapter, the author gives the following summarized statistics for the railways of the United States, compiled from the report of the Interstate Commerce Commission for the year ending June 30, 1906.

STATISTICS OF AMERICAN RAILWAYS. 1906.

Mileage.

Length of line	222,572 miles.
Second track	17,936 "
Third track	1,766 "
Fourth track	1,280 "
Yard tracks and sidings	73,761 "
Total track mileage	317,083 miles.

Employees.

	Per 100 Miles.	Total.
General administration	26	57,054
Maintenance of way and structures	223	495,879
Maintenance of equipment	142	315,952
Conducting transportation	292	649,820
Unclassified	1	2,650
Total	684	1,521,355
Trackmen (433,913, or 195 per 100 miles)	(195)	(433,913)
Section foremen	18	40,463
Section men	155	343,791
Switchmen, flagmen and watchmen	22	49,659
Enginemen, firemen and trainmen	128	285,556
Shopmen	142	315,023
Station agents and men, tel. operators, dispatchers	94	209,808
General officers, clerks	32	70,005
Miscellaneous	93	207,736
Total (nearly 2% of total population)	684	1,522,041

Equipment.

	Locomotives.	Cars.
Passenger	12,249	42,262
Freight	29,848	1,837,914
Switching locomotives and company's cars	8,485	78,736
Unclassified locomotives and fast-freight cars	1,090	*(32,168)
Total (*Fast-freight cars included under freight)	51,672	1,958,912

Traffic.

Passengers carried	797,946,116	Passenger-train mileage	479,037,553
Pass. carried one mile	25,167,240,831	Freight-train mileage	594,005,825
Freight carried, tons	1,631,374,219	Total revenue train mileage	1,105,877,091
Freight carried one mile	215,877,551,241	Av. journey per pass	31.54 miles.
Ave. tons per train	344.39	Av. haul per ton	132.33 miles.

Earnings and Expenses.

	Per Mile of Line.	Total.
Gross earnings from operation	$10,460	$2,325,765,167
Gross income	......	2,386,285,473
Operating expenses	6,912	1,536,877,271
Net earnings from operation	3,548	788,887,896
Net income	1,732	385,186,328
Ratio of total earnings: Passenger		21.93%
Freight		70.54%
Mail and express		4.23%
Operating expenses; percentage of gross earnings		66.08%
" " " of total expenditures (fixed chgs., 27.74%)		72.26%

Rev. per pass. per mile	2.003 cts.	Rev. per pass. train mile	$1.20
Rev. per ton per mile	0.748 cts.	Rev. per frt. train mile	2.60
		Rev. per train mile (all trains)	2.07

Ave. cost of running a train one mile (all trains) 1.37

Earnings per mile of line: Passenger, $2,808; Freight 7,486

Financial.

Assets.		Liabilities.	
Cost of road	$11,588,922,421	Capital stock	$6,929,670,244
Cost of equipment	831,365,517	Funded debt	8,068,004,746
Stocks owned	1,817,242,555	Current liabilities	1,093,207,505
Bonds owned	642,805,004	Int. on funded debt, not yet payable	48,941,415
Cash and current assets	1,259,304,647	Miscellaneous	851,877,671
Materials and supplies	185,228,347	Profit and loss	636,391,319
Sinking funds, etc	130,566,158		
Miscellaneous	1,172,658,251		
Total	$17,628,092,900	Total	$17,628,092,900

Capital: Stock (common, $5,403,001,960)	$6,803,760,093
Bonds and other obligations	7,766,661,385
Total	$14,570,421,478
Per mile of railway	$67,936

CHAPTER 2.—ROADBED CONSTRUCTION.

The general work of railway construction does not come within the scope of this book. It is assumed that the cuts and embankments have been completed to the level of the subgrade; and also that the bridges, culverts, tunnels and other works have been completed. The roadbed (by which is meant the surface at subgrade) has then to be made ready for the track. The tracks are usually spaced 13 ft. c. to c., sometimes 12½ ft. or 12 ft.; and more rarely 14 ft., as on the Illinois Central Ry. Sidetracks are generally 13 to 16 ft. c. to c. from main tracks. The width of roadbed on embankments is from 26 to 33 ft. for double track, and 16 to 20 ft. for single track. The width in cuts, exclusive of the ditches, is from 26 to 37 ft. for double track, and 18 to 25 ft. for single track. The minimum width should be 18 ft. in rock cuts, 20 ft. in earth cuts, and 16 ft. on embankments. It should be at least 3 ft. greater than the width over the toe of the ballast. With narrow banks there is much loss of ballast and more work is required to keep the track in surface, while much material is lost during such work as reballasting, or renewing ties and rails.

The covering of slopes with sod or turf is a matter to which attention is being given in relation to maintenance work. It prevents the erosion of slopes of banks and cuts, and the consequent narrowing of roadbed or filling of ditches. Whether sod should be permitted on the roadbed is a disputed question, with general opinion in its favor. The objection made is that it prevents water from draining off, but water will readily make its way through the sod, especially as the edge of the bank is usually low. The advantage of the sod is in protecting the edge of the bank and preventing erosion. A width of 8 to 12 ins. should be left between the sod and ballast, for convenience in dressing up the ballast, and this strip may be covered with cinders, gravel or screenings. The sod should be used in cuts as well as on banks. The use of sod is practiced on such roads as the New York Central Ry., the Illinois Central Ry., the Delaware, Lackawanna & Western Ry., and the Pennsylvania Lines.

The roadbed is very generally crowned transversely in order to drain water to the sides, but this crowning does not last long, even on a well-compacted roadway. Ballast is driven down into the material, and the original surface soon destroyed. This is now recognized, and the practice of making the roadbed flat is increasing. The crowning in first construction may serve to prevent the surface from becoming concave owing to settlement. Where the roadbed is crowned, it may be formed in different ways: (1) With one or more planes from each side to the center; (2) with a curved surface; (3) with planes from

each side to a flat center portion. A slope will drain better than a flat curve. The rise varies from 3 to 6 ins. for single track, and from 4 to 8 ins. for double track, the smaller heights being the more general. The roadbed may be inclined on curves to conform to the superelevation, but this practice is rare. The more solid and compact the roadbed is made, the better will be the drainage and the more substantial will be the track. The use of horse or steam rollers in consolidating the surface would in many cases have a material influence in reducing maintenance expenses, especially for such work as surfacing and reballasting. This is rarely done, however, and the importance of this matter appears not to be recognized. On an ordinary roadbed the ballast soon begins to work into the surface, and in clay cuts the clay will work up in ridges between the ties. The softer the ground, the greater will be the trouble and there will soon be low spots and an uneven surface. At wet spots, the material should be dug out and replaced with broken stone, slag, sand, cinders or clean gravel. A bed of coarse material as sub-ballast will also be of advantage in many cases. The cause of the trouble should be investigated, and drainage provided if necessary. The aim should be to form a solid and permanent bed for the track and its ballast.

The drainage of the track is one of the most important items in economical maintenance, its importance increasing with the amount of rainfall. This is effected by the ballast and (to an uncertain extent) by the crowning of the roadbed, together with side ditches in cuts to carry away the water from the ballast, roadbed and slopes. There are two general types of ditches: 1, with a trench at the foot of the slope, extending below the roadbed surface; 2, with the roadbed extended on an unbroken incline to the foot of the side slope. Climatic conditions will largely govern the form of cross-section of roadbed and ditches. In dry regions with light soil, trenching is not required, and the second method is suitable. With ordinary rainfall, it is better to have a trench or ditch reaching well below the subgrade, so as to effectually drain the roadbed. Where the rainfall is only moderate, the ditches should still be of ample capacity to carry off the water in occasional heavy rains. The ditches should be kept parallel with the track, and not made to wind around obstructing stumps or boulders. They must be graded to carry water freely and to thoroughly drain the roadbed, so as to keep both roadbed and ballast dry and firm. The width should increase towards the ends, and if the standard width does not give sufficient capacity, the ditch should be widened on the outer side. The distance from the rail to the ditch varies according to the nature of the soil and the standard cross-section of roadbed. It is usually about 5½ to 7 ft. The bottom of the ditch is 12 to 24 ins. wide, and 6 to 18 ins. below the center of the roadbed.

The cultivation of sod through ditches has been tried with success on the Illinois Central Ry.; it is said to increase the economy of maintaining the slopes, as there is no line of bare excavation to be eroded. It does not interfere with drainage if the grass is kept short, and this is easily done. The plan has been tried in cuts where ditches had to be cleaned every year; after the ditches had been shaped and sodded no further treatment was necessary. The use of grass in ditches is not favored as a rule, and where the side of the roadbed forms the ditch it is sometimes sprinkled with oil to keep down weeds. In wet cuts the ditches may be paved with stone or concrete; in narrow wet cuts (especially where the earth slides or bulges) they may be lined with plank or old ties, with struts across the top. Subdrains of tile, brush, etc., may also be laid (see the

chapter on "Drainage and Ditching"). The ditches may be carried under road crossings by cast-iron pipe, clay pipe or wooden box drains. The iron pipe is preferable. Wood soon rots and lets dirt fall in to clog the drain, and clay pipe is liable to be broken, as there is generally very little cover over it. The size of the pipe varies according to the amount of water to be carried, but is generally 6 to 10 ins. The box drains are about 8×10 ins., having plank sides and bottom, and a top of cross strips nailed close together.

Where it is necessary to carry water from one side of the track to the ditch on the other side, or from a center ditch to the side ditches (as on double track), cast-iron pipes or wooden box drains are laid in the ballast, between the ties. The box drains have the ends cut to conform to the slope of the ballast. They are open troughs with four or six flat strips across the top. On the New York Central Ry., with two or more tracks in gravel ballast, these box drains are 6×6 ins., made of 2-in. plank creosoted or treated with three coats of woodiline or fernoline. They are 400 to 500 ft. apart and are placed deep enough to permit tamping. They have an inclination of 1 in. per ft. or more. Stone paving may be laid from the end of the drain to the edge of the bank or ditch. The Pennsylvania Ry. has adopted 6-in. cast-iron pipe for these cross drains.

New York Central Ry. (Fig. 3).—The width of single-track roadbed is 16 ft. for banks (18 ft. for banks over 10 ft. high), and 24 ft. over ditches in cuts;

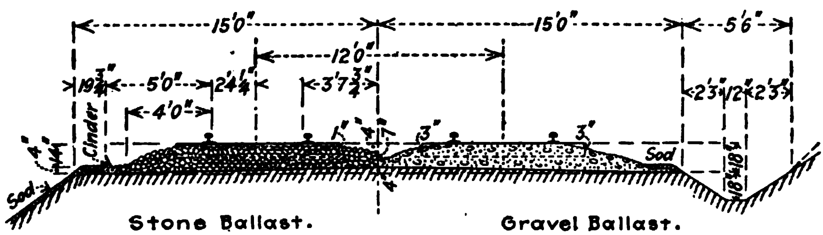


Fig. 3.—New York Central Ry.

the ditches are 12 ins. wide on the bottom and 12 ins. deep. There is a crown of 2 ins. in the width. Double track: 30 ft. wide (41 ft. over ditches in cuts), crowned 4 ins. Four track: 54 ft. wide (65 ft. in cuts), crowned 6 ins. The tracks are 12 ft. c. to c., and on four-track sections the two middle tracks are 2 ins. above the others. The distance between main and side tracks is 13 ft. c. to c. Stone ballast is level, 1 in. below top of ties; at the outer side it is rounded off from end of tie to a line 4 ft. from gage side of rail. Midway between tracks it is 4 ins. below top of ties. Gravel ballast is sloped from top of tie at center to 1 in. below at the rail and 3 ins. below at the ends. At the outer side it is rounded off to a toe line 5 ft. from the rail and 4 ins. above the roadbed. Between the tracks, it is 7 ins. below top of ties. An 18-in. strip of sod is laid along the edge of the roadbed, extending to the ditch or over the side of the bank. This extends to the toe of the gravel ballast, but with stone there is a 12-in. bed of cinders 4 ins. thick between the sod and the ballast. The ditch has sloping sides with the bottom 12 ins. wide and 18 ins. below the edge of roadbed. The height from edge of roadbed to top of tie is 18 ins., except 14 ins. in rock cuts and in new construction. In rock cuts, the double-track roadbed is 27 ft. wide (32 ft. over ditches 6 ins. deep), with a 4-in. crown. The 6-in.

bottom bed of large stone (like telford paving) formerly used, is now used only at track tanks. On new construction a 3-in. course of flat stone is laid, and the roadbed extends to the toe of the slope, the depth being 22 ins. below top of tie. The cross drains have already been mentioned, and in wet cuts there are longitudinal drains between the tracks.

Pennsylvania Ry.—In 1905, a committee of maintenance-of-way engineers was appointed to revise the standard plans for roadbed, and Fig. 4 shows the adopted plan. A special feature is the protection of the slopes of cuts, which are sodded or grown with vines to prevent erosion; they also give a better appearance than the ordinary bare rough earth slope, washed and gullied by rains. This will greatly reduce the work of keeping the ditches clear. Berm ditches are cut at the tops of the slopes on the high sides of cuts. The surface of the track ditch is sprinkled with crude oil to keep down dust and weeds. Ordinarily the sodded slope extends to the toe of the ditch, but in some cases a dry-stone retaining wall is built, as shown by dotted lines. The roadbed has a transverse slope of ¼ in. in 12 ins. (1 in 48) from the center, and in cuts the ditch is formed by a steeper slope extending to the toe of the cut, where the depth is 3 ft. below

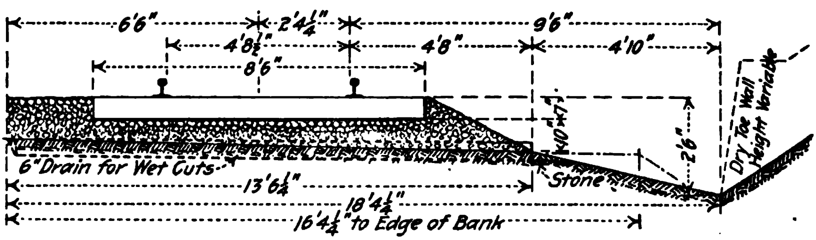


Fig. 4.—Pennsylvania Ry.

base of rail. The bottom of the ditch is 5½ ft. from edge of roadbed, or 10½ ft. from the rail. This provides good surface drainage in ordinary weather, and sufficient waterway for rain storms. Where necessary, as in wet cuts, French drains or 6-in. cast-iron pipes are laid between the ties, discharging into the ditch, as shown. The top of drain is level with top of roadbed. An apron of broken stone is laid at the mouth of the drain to prevent washing of the surface of the ditch. In soft places, a bed of cinders is used under the ballast until the roadbed has settled.

The tracks are spaced 13 ft. c. to c. The ballast cross-section is the same for both stone and gravel. The minimum thickness is 6 ins. below bottom of tie at the middle of the roadbed (8 ins. for single track), and the surface is level with the tops of the ties for the full width. At the sides it is sloped off directly from the ends of the ties. Under the outer ends of the 7-in. ties, the ballast is 12 ins. thick. The widths of roadbed, etc., are tabulated below. Where an industrial spur or siding is laid, it is 16 ft. c. to c. from the nearest main track, and the extra width of roadbed is sloped 1 in 36. Gravel or cinder ballast is used for such tracks, 12 ins. deep below top of tie, and sloped from the ends to the roadbed. Where necessary, 6-in. cast-iron cross drains are laid, as already described, to carry water from the main track to the ditch.

	Width of roadbed. Cuts (ex. of ditches). ft.	ins.	Banks. ft.	ins.	Ballast. Width over toe. ft.	ins.	Quantity per mile. cu. yds.
Single-track	19	8½*	19	8½	13	8½	2,629
Double-track	36	8½	32	8½	27	0½	5,127
Four-track	64	8½	60	8½	53	8½	11,632

* Width 23 ft. 8½ ins. for heavy traffic.

New York, New Haven & Hartford Ry. (Fig. 5).—The roadbed is practically flat, being crowned only 3 ins. in a 57-ft. width for four tracks, so that it will not become concave by settlement. With stone ballast this slope extends to the edge of the cut or bank, but with gravel ballast there is a 6 to 1 slope from toe of ballast. The total width is 18 ft. for single track, 31 ft. for double track and 57 ft. for four track; this is the same for both cuts and banks. The tracks are 13 ft. c. to c. (formerly 12 ft., as in Fig. 5). Stone ballast is level with the tops of the ties, shouldered out 12 ins. beyond their ends, and then sloped 1 on 1 to the roadbed. It is 17 ins. thick at the middle (four-track) and 20 ins. at

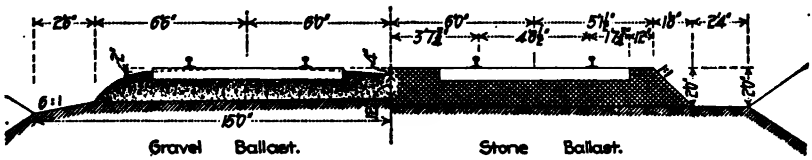


Fig. 5.—New York, New Haven & Hartford Ry.

the ends. Gravel ballast is level with the tops of the ties for 18 ins. at the middle of each track, and then sloped to 2 ins. below top of tie at the ends. It is 11 ins. thick at middle of four-track roadbed (12 ins. for double track), and 16 ins. at the ends. Box drains are placed at intervals to carry water from the central depressed drain or ditch in the ballast to the side ditches. With 8-ft. ties the ballast toe is 2 ft. 6 ins. from end of tie with gravel, and 2 ft. 8 ins. with stone.

Baltimore & Ohio Ry. (Fig. 6).—The standard designs are made for three classes of track, according to the classification of the American Railway En-

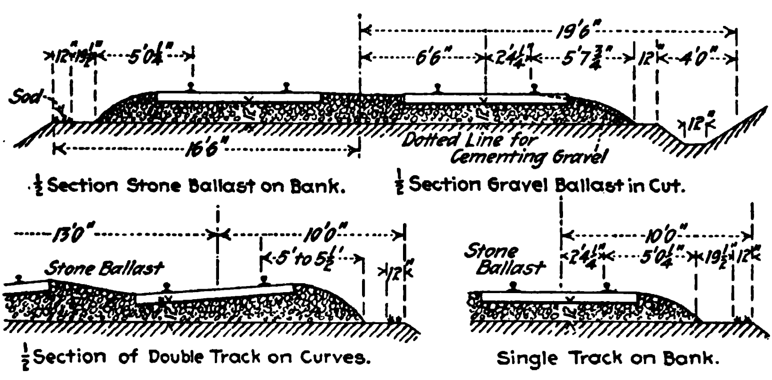


Fig. 6.—Baltimore & Ohio Ry.

gineering Association, already noted. The roadbed is flat, and the side ditches have a uniform bottom width of 12 ins. The dimensions for both stone (and

hard slag) and gravel ballast are tabulated below, but the figures for Class C are below what is generally considered as the proper minimum.

	Class A (double). ft.	ins.	Class A (single). ft.	ins.	Class B (single). ft.	ins.	Class C (single). ft.	ins.
Width of roadbed: banks	33	0	20	0	18	0	16	0
Width of roadbed: cuts	31	0	18	0	16	0	14	0
Width over ditches: cuts	39	0	26	0	24	0	22	0
Ballast, depth under ties	1	0	1	0	..	9	..	6
Width over ballast: gravel	29	0	16	0	14	0	12	8½
Width over ballast: stone	27	9	14	9	14	4	14	0

Delaware, Lackawanna & Western Ry.—The double-track roadbed (Fig. 7) is 32 ft. 0½ in. wide, with a crown of 5 ins. at the center, and the ballast width is 26 ft. 1½ ins. Stone ballast is 8 ins. deep under the ties at center of roadbed, and its surface is flat, but 2 ins. below the tops of the ties. Between the tracks it is slightly depressed, and the ends are rounded off sharply, leaving a 3-ft. berm. The ditch has its inner edge 12 ins. beyond and 18 ins. below edge of roadbed; it is 12 ins. wide on the bottom and the outer side has a slope of 1 on

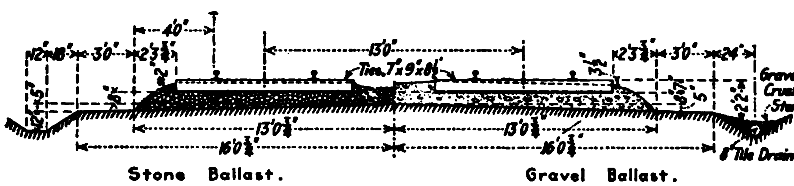


Fig. 7.—Delaware, Lackawanna & Western Ry.

1½. Gravel ballast is level with top of tie at middle of track and sloped to 3½ ins. below at the ends. A V-shaped ditch is employed, with an 8-in. tile drain whose top is 26 ins. below top of tie, and its center line is 2 ft. from edge of roadbed. Gravel or broken stone is filled in over this, with a concave surface. On single track, the roadbed is 19 ft. 1½ ins. wide, with a crown of 3 ins., and the width over ballast is 13 ft. 1½ ins. Stone ballast is shaped as already described, but gravel is sloped to only 1½ ins. below the top of tie; it is 10¾ ins. deep under the center of the tie.

Virginia Ry.—This important road, built in 1906–1907, adopted a width of 18 ft. on banks and 16 ft. in earth cuts (22 ft. over ditches), with a crown of 2 ins. in both cases. In rock cuts the width is 15 ft. (20 ft. over ditches). The stone ballast brings the top of the ties 13 ins. above grade; it is 7 ins. deep under the rails, and sloped to 2 ins. below top of tie at ends. The width over ballast is 12 ft. 8½ ins. The ditches in earth cuts are 12 ins. deep, with 1 on 1 side slopes; in rock cuts they are 6 ins. deep.

Chicago & Eastern Illinois Ry. (Fig. 8).—The roadbed is flat. The width for both cuts and banks (under the classification already mentioned) is 20 ft., 18 ft. and 16 ft. for single track; and 33 ft., 31 ft. and 29 ft. for double track. The tracks are 13 ft. c. to c. In cuts, there is a slope of 1 on 1½ from edge of roadbed to the flat bottom of the ditch. Ballast of stone, slag, gravel, disintegrated granite and cinders is sloped from middle of tie to 1 in. under the rail and 1½ ins. below top of tie at ends (8-ft. ties). It is then rounded off to a curve of 2¼ ft. radius and sloped 1 on 2 to the roadbed. On double track, it is depressed 2½ ins. below top of ties at the middle. With chats and sand, the ballast is sloped to 1 in. below top of tie at ends, and then rounded off on a curve of 6½ ft. radius,

extending to the roadbed. With earth, the ballast is 2 ins. above tie at middle, rounded off and sloped to bottom of tie at end; then sloped 1 on 10 to edge of ditch or cut. Sod is grown on the edges of banks to a width of 12 ins., but with

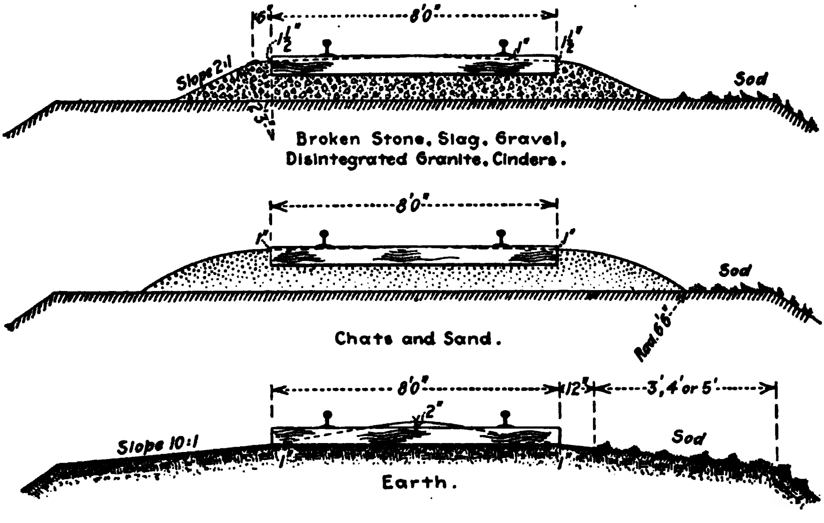


Fig. 8.—Chicago & Eastern Illinois Ry.

earth ballast it extends to within 1 ft. of ends of ties. The depth of ballast under the ties varies from 6 to 9 ins.; and quantities, etc., are as follows:

Depth of ballast.	Stone and gravel.						Chats and sand.					
	Width of ballast.				Ballast per mile.*		Width of ballast.				Ballast per mile.*	
	Sin. t.		Dble. t.		Sin. t.	Dble. t.	Sin. t.		Dble. t.		Sin. t.	Dble. t.
ins.	ft.	ins.	ft.	ins.	cu. yds.	cu. yds.	ft.	ins.	ft.	ins.	cu. yds.	cu. yds.
9	13	6	26	6	2,276	4,912	15	2	28	2	2,705	5,408
8	13	2	26	2	2,061	4,486	15	0	28	0	2,476	4,967
6	12	6	25	6	1,644	3,645	14	6	27	6	1,988	4,055

* Quantities allowing 3,200 ties per mile; ties, 6×8 ins., 8 ft. long.

Illinois Central Ry. (Fig. 9).—The roadbed is flat under the ties and then has a fall of 6 ins. to the edge of bank or ditch. The slopes are sodded, the sod extending on the roadbed to toe of ballast, and lining the ditches in cuts, as already noted. The ditch is formed by a slope from the roadbed, and is 12 ins. below and 4 ft. from edge of roadbed. On double track, the tracks are 14 ft. c. to c., and the ballast (of whatever kind) is formed to a center drain 8 ins. deep. For first-class track the ballast is uniformly 12 ins. deep under the ties, with side slopes of 1 on 1½ for stone, gravel and cinders. The particulars for second- and third-class track (under the classification already mentioned) are tabulated below. With cementing gravel, the ballast is filled 3 ins. over the ties for 4 ft., then sloped to the bottom of tie and then to the roadbed at a distance of 2 ft. 3 ins., 1 ft. 9 ins. and 1 ft. 3 ins. for the three classes; all with ties 8½ ft. long. Earth ballast is used only on third-class lines; it is sloped the same as cementing gravel, meeting the roadbed at the bottom of the end of tie.

The quantities of ballast, etc., are as follows: With earth there are 499, 541 and 551 cu. yds. per mile with the three sizes of ties noted.

Ballast.	Ties.			Ballast: cu. yds. per mile. Double track.	Single track. Class A.	Class B.	Class C.
	ins.	ins.	ft.	cu. yds.	cu. yds.	cu. yds.	cu. yds.
Stone	6	8	8	6,891	3,488	2,962	....
Stone	7	9	8½	7,341	3,784	2,966	....
Stone	7	9	9	7,496	3,916	3,081	....
Gravel and cinders	6	8	8	7,325	3,825	3,014	2,287
Gravel and cinders	7	9	8½	7,924	4,168	3,311	2,536
Gravel and cinders	7	9	9	8,061	4,302	3,428	2,635
Cemented gravel	6	8	8	.....	2,747	2,291	1,868
Cemented gravel	7	9	8½	.....	2,887	2,414	1,975
Cemented gravel	7	9	9	.....	2,995	2,506	2,050
				ft. ins.	ft. ins.	ft. ins.	ft. ins.
Width of roadbed, bank (gravel ballast)				34 0	20 0	18 0	16 0
Width of roadbed, cut (gravel ballast)				46 6	32 6	30 6	28 6
Width of ballast (gravel ballast)				31 6*	17 6	16 0	15 0
Ballast under ties (gravel ballast)				1 0	1 0	.. 10	.. 8

* With stone ballast, 30 ft. 4 ins.

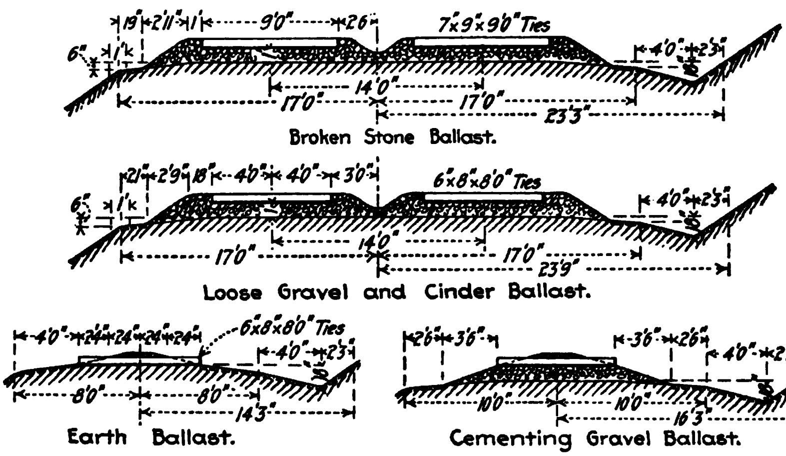


Fig. 9.—Illinois Central Ry.

Atchison, Topeka & Santa Fé Ry. (Fig. 10).—The width of single-track roadbed is 26 ft. in cuts, 18 ft. on banks (20 ft. if higher than 10 ft.). The middle is level, with slopes of 1 on 8 to the toe of cut or edge of bank. With 8-ft. ties, the ballast is level with the top for 9 ft., and has side slopes of 1 on 1½. This section is for stone, clean gravel, chert and burned clay. With cementing gravel, it is level for 3½ ft., then sloped to 3 ins. below top of tie and continued to a width of 10 ft. 4 ins., beyond which is a side slope of 1 on 2. The width over ballast is 17 ft. 4 ins. Earth, or material that will not drain, is filled in 3 ins. over the ties for 2 ft. and then sloped to bottom of tie at the end. Beyond this is a slope of 1 on 8, the width being 18 ft. on banks and 23 ft. in cuts. Through the deserts, the road is built on a 16-ft. bank with slopes of 1 on 1½, and the ties are bedded flush with the top of the bank. The quantities of ballast per mile are as follows:

Depth under ties	12 ins.	10 ins.	8 ins.	6 ins.
Stone, gravel, chert, burned clay; cu. yds.	3,400	2,880	2,410	1,940
Cementing gravel; cu. yds	3,470	2,930	2,380	1,880

Kansas City Southern Ry. (Fig. 11).—The width of roadbed is 18 ft. on banks and 17 ft. in cuts (20 ft. over ditches). It is crowned with a slope of 1 in. per ft., and side slopes of 5 ins. per ft. to toe of cut. The ballast is level with

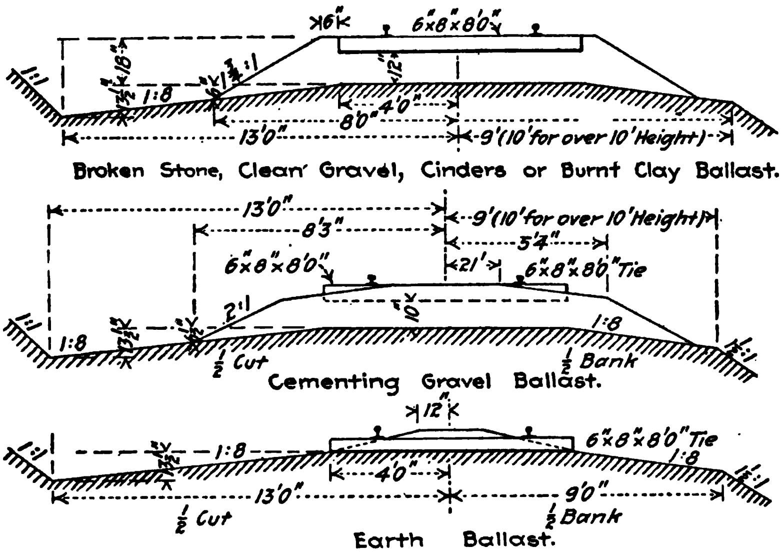


Fig. 10.—Atchison, Topeka & Santa Fé Ry.

top of ties (8 ft. long), extending 6 ins. beyond their ends, and then sloped 1 on 2. This is for washed gravel, chats (from the Joplin zinc mines) and cinders. The depth is 10 ins. under middle of tie and 12 ins. under the ends.

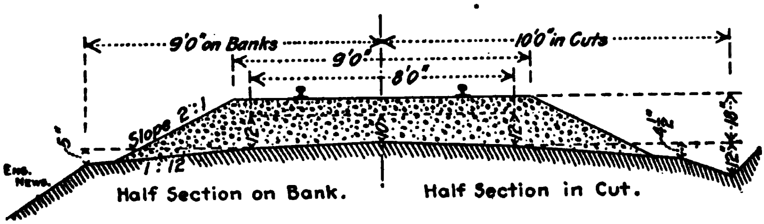


Fig. 11.—Kansas City Southern Ry.

Bridges and Viaducts.

Masonry structures usually have the floor shaped to form drainage planes and ditches or gutters. The drains may be carried along the structure or lead to weeper holes or pipes forming outlets at the haunches of the arches, either at the spandrel walls or in the intrados of the arch. In the masonry viaduct approaches of the Mississippi River bridge at Thebes, Ill., the space between the spandrel walls is filled with red gravel, compacted by flooding. The surface of this slopes from the crowns of the arches to the piers and from the sides to the center. In the longitudinal valley is a drain of 6-in. tile, connecting with a 6-in. vertical drain in the middle of each pier, the latter having a lateral outlet

at the ground level. A branch from the vertical pipe has a grating (covered with large stones) flush with the top of the pier, and serves to drain away water that passes through the filling. In some recent concrete arch structures, flat slab floors are used, requiring no spandrel filling. The floor construction of steel bridges and timber trestles is discussed in the chapter on "Bridge Floors."

Tunnels.

The roadbed arrangement will depend upon the style of floor, the amount of water to be dealt with, and the character of the ballast. In rock tunnels the floor is generally flat, sometimes with a trench drain down the middle, covered by flat stones to keep out the ballast, or else a pipe drain is laid in the trench, and the ballast is filled in around it. With this arrangement the ballast is usually filled in level with the ties for the full width of the tunnel; if there is no drain, the ballast may be sloped in the usual way to form side and center ditches. If the tunnel has an invert, there is usually an arched or box drain of brick or dry stone masonry, built upon the invert and covered by the ballast, although sometimes a pipe drain is laid in the ballast. The brick and stone drains in the Howard St. tunnel of the Baltimore & Ohio Ry. at Baltimore are shown in Fig. 12.

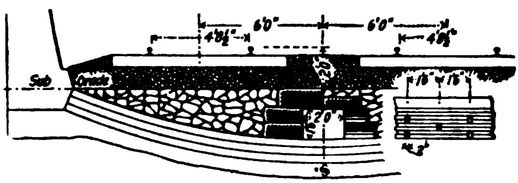


Fig. 12.—Baltimore Belt Line Tunnel; Baltimore & Ohio Ry.

In the arrangement in the Aspen tunnel of the Union Pacific Ry., Fig. 13, it would seem desirable to keep the ballast further away from the ditches. In the

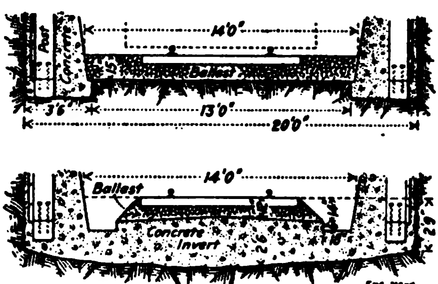


Fig. 13.—Tunnel; Union Pacific Ry.

tunnels on the Everett & Monte Cristo branch of the Northern Pacific Ry., Fig. 14, the concrete floor forms a trough for the ties and ballast. The bottom is only 15 ins. below level of rail head, so that there is not much ballast. Outside of this trough is a rectangular ditch on each side. In the tunnels of the South & Western Ry., 18 ft. wide, the rock floor is flat, with ballast 15 ins. deep below top of tie; at each side is a ditch 16 ins. wide and 18 ins. deep. On the Virginia Ry. there is a fall of 6 ins. in the 16-ft. rock floor to a rectangular trench

18 ins. wide. This is filled with loose stone, in which is embedded a tile drain w often
open joints. The stone is filled in to form a level bed on the tunnel floor fo ditions,
ordinary ballast (8 ins. deep under the ties and 12 ft. 8½ ins. wide), le s, and of
strip of floor bare at each side. In the double-track tunnels of to consider
Francisco cut-off of the Southern Pacific Ry. the 30-ft. concrete lies especially
fall of 3 ins. to the center, where a tile drain is laid in the ballast n rails laid upon
is filled in level with the ties from wall to wall. Double-tr itudinal timbers.
ansit underground
ug. 2 and Sept. 20,

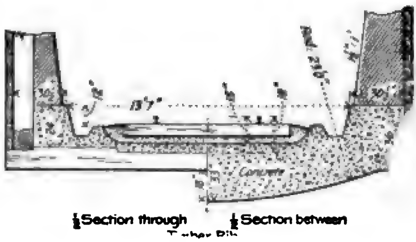


Fig. 14.—Tunnel; Northern Pacific Ry. track, with economy in
ribute the load over the
the Harlem Division of the New York Central Ry. hav efficient drainage under
26-ft. rock floor to a central trench with tile drain. Th sing track without dis-
crete walls form the bottom of the ditches (level with r oadbed is finally com-
are clear of the ballast. Long tunnels have refuges 3 ft. w grade. The quantity
each side, staggered in position. nder the ties for track

For rapid-transit underground railways and circular a as possible. Where
special systems of construction are used. The New York ast will be found to
transit subways use ballast and ties, but in the former the from being worked
trench 10 ins. deep and 8 ft. 10 ins. wide, leaving only a 5-in proper, but a bed of
under the 5-in. ties. Where an invert floor is used, as at Bo into the roadbed it
from 6 to 24 ins. under the ties. The Philadelphia subway, F ramping and filling
being very uneven
ort under the ties.
consolidating the
it with a founda-
gh quarry stones
s, gravel, coarse
e roadbed from
roadbed.
12 ins. for first-
he Pennsylvania

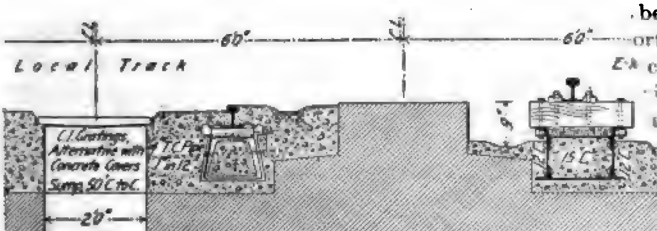
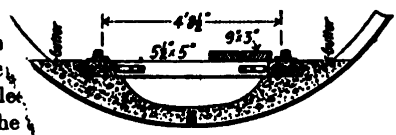


Fig. 15.—Underground Railway; Philadelphia Rapid Transit nd the Michigan
The minimum
concrete floor that can be flushed and washed. The local tracks n should be the
supported on cast-iron chairs embedded in the concrete. The e the depth used
have the rails laid on wooden blocks 6×10×24 ins.; these rest upo traffic, and it
tudinals embedded in the floor, each consisting of a pair of 12-in. er quality) of
ins. apart, connected at intervals by horizontal diaphragms of 15-i t and roadbed
A plan proposed by Mr. J. W. Schaub provides for a reinforced co pter 1. The
with the top level with base of rail in the middle. A bench at each s ffect on loco-
seat for a longitudinal timber 12×12 ins., transverse rods or bo ballast will
through the timbers and the middle part of the floor. From the bot n roads with

at t he concrete is extended to the tunnel wall and forms a drain. The large ion of the floor may be hollow, forming a conduit for pipes, wires and passes track would consist of tee rails resting on tie-plates and secured by floors are

bridges and London Ry. (England) is an electric underground line with a pair rcular tunnels. The floor is of concrete so shaped as to form for two lines of longitudinal oak timbers 5×11 ins., with a , as shown in Fig. 16. At intervals of 7½ ft. there are oak

The roadbed a water to be dealt floor is generally fl by flat stones to ke and the ballast is fille filled in level with the ballast may be sloped tunnel has an invert, stone masonry, built v times a pipe drain is Howard St. tunnel of t

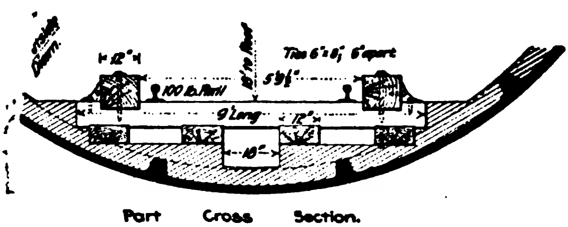


–Underground Railway; Central London Ry.

tween the longitudinals. The rails are 60 ft. long, of de, 3½ ins. high, weighing 100 lbs. per yd. They are als by fang-bolts 2 ft. 8 ins. apart, alternating on either These bolts have square heads and are screwed down ur nuts placed under the timbers, the nuts having points the wood, and so prevent them from turning. The rails oints, with a ribbed base plate, ½×7×20 ins., under the e hollow of the rail. The end of each rail is held by four so two ¾-in. holes for the rail bonds. Some of the later lines in London have double-head rails in chairs on ties dle on a concrete base about 3 ft. wide, with stone ballast

Fig. e Great Northern & City Ry., however, uses 85-lb. tee rails, der tie-plates 10×8 ins., 26 ins. apart. These are laid on

In the arranger , 6×12 ins., on a bench in the concrete floor, with transoms would seem desir timber joints). Fang-bolts are used on the inside and 6-in. outside of the rail. Fig. 17 shows the unballasted floor con-



Part Cross Section.

Fig. 17.—St. Clair Tunnel; Grand Trunk Ry.

circular, iron-lined tunnel of the Grand Trunk Ry. under the The concrete floor is shaped to form a central drain with bear-

tunnels on th dinal timbers supporting the ties, which are 6×8 ins., 6 ins. 14, the conc ler construction is to lay the rails directly upon the longitudinals, only 15 ins. any English tunnels.

of this trou l in tunnels is practically free from heaving or settlement, having & Western f rock or concrete. Ballast, therefore, is not required to protect top of tie; e roadbed, but only as a cushion bed for the ties. The depth of ginia Ry. th

ballast is sometimes so small as to be of little value in this respect, and very often it cannot be increased on account of limited clearance. These conditions, coupled with the difficulties of maintenance and renewals in tunnels, and of keeping track in surface on a thin bed of ballast, make it desirable to consider the use of a more permanent type of track construction. This applies especially to rapid-transit tunnels. A concrete floor has been proposed, with rails laid upon or embedded in it, or supporting an open floor of ties or longitudinal timbers. This matter, as related to both ordinary tunnels and rapid-transit underground lines, has been discussed very fully in Engineering News, Aug. 2 and Sept. 20, 1906 (pages 113, 123, 310 and 314).

CHAPTER 3.—BALLAST.

The ballast is a most important item in securing good track, with economy in maintenance and operation. Its purposes are (1) to distribute the load over the roadbed, (2) to form a support for the ties, (3) to provide efficient drainage under and around the ties, and (4) to allow of surfacing and raising track without disturbing the roadbed. It should not be laid until the roadbed is finally completed to grade and should not be used for raising banks to grade. The quantity of ballast should be liberal, with a depth of at least 12 ins. under the ties for track with heavy traffic, and the depth should be kept as uniform as possible. Where an old roadbed has been frequently reballasted, the ballast will be found to extend to a considerable depth, gradually becoming poorer from being worked into the soil. This makes a good foundation for the ballast proper, but a bed of sub-ballast would be cheaper. As the ballast gradually works into the roadbed it necessarily settles from beneath the track, so that continual tamping and filling are required to maintain the track in surface. The settlement being very uneven it is difficult to maintain a uniformly good ballast and support under the ties. Under these conditions it is well to provide for thoroughly consolidating the roadbed in the first place (as already noted), and then to cover it with a foundation cause of sub-ballast. This may be a 6 to 8-in. bed of rough quarry stones laid on edge, as in telford paving; or it may be of broken brick, gravel, coarse slag or cinders. This foundation will assist drainage, keep the roadbed from becoming soft, and keep the ballast proper from sinking into the roadbed.

The standard depth of ballast under the ties is generally 8 to 12 ins. for first-class track. Anything more than 12 ins. is exceptional, but the Pennsylvania Lines use 13 ins. On the Lake Shore & Michigan Southern Ry. and the Michigan Central Ry., 8 ins. and 6 ins. of stone are laid on 6 ins. of gravel. The minimum depth on main track should be 8 ins., and on curves the minimum should be the standard depth under the low rail. There are many cases where the depth used is not sufficient to properly support the weight and amount of traffic, and it would often be economical to use a greater quantity (and better quality) of ballast. The relation of weight of traffic to the resistance of ballast and roadbed is rarely given consideration, but this has been discussed in Chapter 1. The material should be carefully selected, as it may have a decided effect on locomotive and car maintenance, as well as on the traffic. A dusty ballast will cause greatly increased wear of the journals and machinery, and on roads with

extensive passenger traffic it is as important to avoid dust and dirt by the use of clean ballast, as it is to avoid smoke and cinders by the use of hard coal or coke for fuel. This is one of the principal reasons for sprinkling dusty ballast with oil, as noted further on.

The best ballast is that which will best form a durable support to the ties, retain its solidity and position under the disturbing effects of weather and traffic, give good drainage, be free from dust, and make an easy riding track. Where water is retained under and around the ties, the ballast will soon deteriorate and be churned up, and bad track will result. In material that does not drain well the ends of the ties should be left entirely free, in order to allow water to escape quickly from under them, as in such material the ties will churn the wet ballast into mud. In many cases an expensive ballast hauled from a distance will be more economical than cheaper and inferior material nearer at hand. This applies especially to roads with heavy traffic.

The materials most generally used are broken stone, gravel, furnace slag, burned clay, sand, cinders and earth. Shells, chert, etc., are also used locally. Stone ballast will drain readily (while clean), but gravel, burned clay, earth, etc., will retain water more or less (according to quality), and are liable to heave after frosty weather. The form of cross-section given to the bed of ballast varies with the material, the climate, and the ideas of the engineers, but several forms have been shown in Figs. 3 to 11. The ties should not be covered with ballast as a rule, as it prevents inspection, and leads to rotting by keeping the ties damp. In hot dry regions this may be permissible, in order to protect the ties from the sun. Earth ballast, however, is usually filled over the ties.

Broken Stone.—This is in general the best material for ballast, as it meets all the requirements above noted, and can be worked in wet or dry, cold or hot weather alike. The best stone is hard and tough, which will not disintegrate by climate or crush into dust by tamping or under the traffic, and which breaks into cube-shaped or angular pieces instead of thin flat pieces. Granite, trap and limestone are most used. The stone should be broken to a uniform size, and this has varied from 2 to 3 ins., but the present tendency is to use smaller stone. Stone broken to a ¾-in. size and screened has been used with good results; it is less noisy, wears the ties less, can be tamped more easily, and gives a better surface with less labor. Very coarse stone leaves too many voids, reducing the stability and increasing the difficulty of getting the track in good surface. In fact, it has sometimes been found desirable to apply a top dressing of screenings upon such ballast, making a close and dense mass which affords excellent support and is yet practically free from dirt. The American Railway Engineering Association recommends that the minimum size should not pass through a screen with ¾-in. holes, and the maximum should not exceed pieces which will pass through 2-in. holes. On several roads a 1½-in. or 2-in. size is specified, or sizes ranging from ¾ in. to 2 ins.; some go as high as 2½ ins., but rarely more. The Central Ry. of New Jersey, however, specifies 2¾ ins. for trap rock. Crusher-run stone screened to exclude only stones above the maximum size is not generally satisfactory. Where possible it is best to get the coarser material at the bottom, and the fine screenings at the top for surfacing. In cross-section, the ballast is usually level with the tops of the ties, and is either extended or shouldered out 6 to 12 ins. beyond their ends so as to hold the track in line, or is sloped or rounded off from the ends of the ties. It is better, and looks neater, to shoulder it out, especially with coarse stone, with which there is more tendency to lateral motion

of the ties on curves. A slope of 1 on 1½ is usually sufficient, but 1 on 2 is sometimes preferred. The slopes are sometimes hand faced for appearance, and the toe is very generally lined up, using a board against which a row of stones is laid by hand. On double track, the ballast is generally continued level across the whole width, with sometimes a row of large stones between the tracks to form a drain, these being covered with the regular ballast. In other cases it is sloped to form a center drain. Large stones may be laid between the tracks and behind the bank sills of trestles, etc., but must never be placed directly under the ties.

Stone ballast should be handled with forks instead of shovels, so as to avoid putting dirt into the track, which will hinder drainage and afford a chance for weeds to grow. While stone ballast will drain readily when clean, this is not the case when it is clogged with mud working up from the roadbed and cinders and dust from above. For this reason even stone ballast should be kept clear of the rails where a track circuit is used, so as to avoid any chance of holding water against them. To effect this, some roads keep the top of stone ballast 2 ins. below the rails for the entire width. Dirty stone ballast may often be made almost as good as new by digging it out and screening it. Near large cities this will often produce an almost incredible quantity of fine dirt, the accumulation of city dust and soot. On the New York Central Ry. Lines at New York, the stone ballast is 12 ins. deep under the ties, and is cleaned every year by turning it over with forks. From a maintenance point of view it may be noted that stone ballast on a poor road may involve greater expense for renewal (perhaps at a time when little money is available) than would be required for gravel. While the first cost of stone ballast is considerably greater, and the cost of maintenance is sometimes more, yet there is less liability of washouts, weeds do not grow, there is no dust, and the track holds its line and surface better.

Gravel.—This material is more used than any other, and is of very varying quality. It may be coarse and clean, or sandy and dusty, or loamy and cementing (when weeds will grow, drainage will be affected and the track will heave); or it may be full of large stones, in which case it will make an irregular and rough riding track. Cementing gravel (containing clay) should be avoided as far as possible. The best gravel is clean and coarse, with stones of small and fairly uniform size, and as little sand as possible. Only very clean gravel will drain as well as stone. It is good economy to use plenty of gravel, giving at least 10 ins. (or better 12 ins.) under the ties, as this will enable a fairly good track to be maintained nearly all the year through without excessive work. It can be tamped by picks or bars, the latter being usually preferred, and is easily taken care of. Sandy gravel may cause undue wear of tires, journals, etc., as well as discomfort to passengers. As a general thing, the gravel excavated at the pit is put directly into the track, although it usually contains a considerable portion of undesirable material. A few railways have experimented with screened and washed gravel with good results, and the development in better construction and maintenance is likely to increase the use of such material. In Europe, gravel is very frequently screened and washed by machinery to free it from clay, earth and sand, and this practice is coming into use in this country. Screened gravel is used to some extent on the Pennsylvania Lines and the Lake Shore & Michigan Southern Ry.; the bank gravel contains 50 to 70% of sand, so that it is difficult to maintain the track in surface, the rains causing continual settlement by washing out the sand. In the screening plants of the latter road, the capacity is such as to handle the product from a 75-ton 3½ yd.

steam shovel at the pit, so as to furnish as much screened ballast per day as the shovel could furnish of unscreened ballast. This avoids a tendency to use ordinary gravel on account of insufficient supply of the better material. The gravel is dumped from drop-bottom cars into a hopper, from which an inclined belt conveyor carries it to a chute, down which it is washed by a jet of water. A bar screen removes all stones over 2 ins., these are delivered to a crusher, whose product is elevated to the chute. The material passing this screen goes through a $\frac{3}{4}$-in. screen, then $\frac{1}{4}$-in., and finally a double screen of $\frac{3}{16}$ in. and $\frac{1}{8}$ in. close together. The gravel falls upon the inclined face of each screen, and that going through rolls down a platform to the next one; that held by the screens falls direct to the bin above the loading track. The sand goes to a settler and another bin. Stationary screens are used, other plants have revolving screens. The cost is about 23 to 30 cts. per yd., while stone costs 50 to 75 cts. The material is used to give the track a general raise of about 6 ins., covering the old dusty ballast. It has given good service, but stone will probably be adopted eventually on the main line. (Engineering News, Aug. 1, 1907.)

Washed gravel, which in the bank contained such a proportion of clay as to be unfit for ballast, is being successfully used on the Kansas City Southern Ry. (Fig. 11). This was first produced by a portable plant, as also used on the Chicago & Alton Ry. (Engineering News, Feb. 18, 1904). Better results have been obtained with a stationary plant. The clayey-gravel above mentioned is washed in a plant having 18-in. troughs 18 ft. long, in each of which is a shaft with spiral blades which churn the material and carry it up the trough, the upper end of which is 6 ins. above the lower. The troughs are set in a tank, and above and between each pair is a 5-in. pipe with $\frac{3}{4}$-in. holes 3 ins. apart through which streams of water are delivered into the trough. The clean gravel discharged from the upper end is elevated to storage bins. It ranges in size from $\frac{1}{8}$ in. to 3 ins. It would be of better quality if the very small and very large sizes were excluded. In a combined washing and screening plant, a jet washes the material down a hopper with stationary screens below. Plants of this kind were described in Engineering News, Aug. 1, 1907.

There are various forms of cross-section used, depending upon the quality of the material and the climatic conditions. With good, clean coarse gravel, particularly in warm dry regions, it is better to bring the ballast level with the top of the ties, and shoulder it out 6 to 12 ins. beyond them. The side slopes may be 1 on 2. With inferior, fine or loamy gravel, and where water and frost have to be considered (especially in connection with track circuits), it is better to have it level with the ties for only about 30 ins.; sloping then (or from the middle) to 2 or 3 ins. below the top of tie at the ends. This will allow water to drain off rapidly, the ballast being about 1 in. below the rails. With cementing gravel or chert, the slope should be from the top of tie at the middle to the bottom at the ends, and then 1 on 3 to the roadbed. The gravel is sometimes filled in 2 or 3 ins. over the middle of the ties. In wet country this would keep them damp and lead to rotting. In dry country, however, it may protect them from the sun, as well as from the engine cinders. The Houston & Texas Central Ry. at one time filled in the gravel between the rails almost to the level of the under side of the rail heads, completely covering the ties. It is true that this causes a somewhat more rapid decay of the ties, but the gravel was of such quality that the track could not be properly held without covering them either at the middle or the ends. The practice has been changed (to conform to that of allied lines),

but it is still considered better to fill in as described and to leave the ends free so as to provide better drainage. It was also found that track thus filled held its line better than when the ballast was level with the tops of the ties and had a 6-in. shoulder at the end. On double track, gravel ballast is very generally sloped to form a drain or trench between the tracks.

Slag.—Blast furnace slag is extensively used on roads in the vicinity of furnaces and steel works. It is of varying quality, but the best is about as durable as broken stone and in other ways almost as good. The objection that it causes corrosion of the rails is not sustained by experience. Coarse, spongy slag is apt to pulverize and deteriorate, both in tamping and under the effects of traffic, but the most satisfactory results are obtained from the finer glassy and hard slag. There is now comparatively little lump slag produced. Some of the slag is excavated by steam shovels from slag banks a year or more old. This material is loosened by blasting, then crushed, screened and handled like stone. At many furnaces the stream of molten slag is struck by a horizontal jet of water, causing it to break up into particles like clean fine gravel but very light in weight. Heavier and finer material, like coarse sand, is obtained by the use of both a vertical and a horizontal jet. The granulated slag weighs only 15 lbs. per cu. ft. when dry, and it drains rapidly. The form of cross-section should be similar to that for clean gravel. The Norfolk & Western Ry. uses slag, as there are several furnaces in Virginia furnishing a hard silicious slag that makes good ballast. As it is poured from the slag car it falls over the bank in a thin sheet, and the cooling effect of the air causes it to break up in small pieces. Most of the material as loaded by steam shovels is ready for use in the track. It is as durable as good stone ballast, and is very much cheaper. As this road handles much coal, coke and iron ore, any ballast soon gets clogged up, and renewals with stone would be expensive.

Burned Clay.—This has been used in England and other foreign countries for many years, and its use is extending in this country, mainly in the West. Brick clay is the most suitable, but almost any clay that has not too much sand may be used, as well as "gumbo" or clayey earth. The site for burning is cleared of top soil, and a row of cordwood, old ties, etc., about 3 ft. high, is laid the length of the kiln, 500 to 4,000 ft. This is covered with a few inches of slack coal, or slack and lump mixed, upon which is 9 to 12 ins. of clay. The wood is then lighted at intervals, the openings being closed when the fire is started. As the burning proceeds, another layer of coal is placed and another layer of 6 to 9 ins. of clay; these layers are repeated from time to time until the finished heap is about 20 ft. wide and 10 ft. high. One ton of slack coal will burn 3 to 5 cu. yds. of clay, and the material swells in burning, so that a cubic yard of clay will make nearly two yards of ballast. About 1,000 cu. yds. per day can be burned in a kiln 4,000 ft. long, about 50 men being employed. The work is very generally done by contract, the company furnishing the land, sidetrack and coal. Partial estimates are given on kiln measurements, and the final estimate is made from car measurements when loaded out, so that worthless material is not paid for. Unless the material is thoroughly burned and by a clean fire it is liable to disintegrate and turn to dust and mud. The absorption of water should not exceed 15% by weight.

The ballast is light (40 to 50 lbs. per cu. yd.), and should be used in liberal quantities to give good results and hold the track in line. The ballast cross-section is similar to that for stone, the material being well shouldered out and

at least 12 ins. deep under the ties. It is easily handled, drains well, does not heave, is free from weeds, is not dusty, and is in general satisfactory, requiring renewal in 6 to 8 years. The cost is from 50 cts. to $1 per cu. yd. Burned black-wax soil has been used with success on the Texas Midland Ry. since 1896, and costs about 90 cts. per cu. yd. in the track. It is very absorbent, for with only 6½ ins. under the ties there has been no trouble with a soft roadbed, and examination made after 36 hours' rain has shown dry ballast 4 ins. below the bottom of the tie. It holds the track well, and during nine years it has required only 30 car loads per mile for renewals.

Cinders.—Engine cinders make a cheap and serviceable ballast which will last for some time under light traffic. Being porous, it drains well and does not hold moisture, but it is apt to make a dusty track for a time, until the rain and traffic have thoroughly compacted it. It is sometimes applied over a bed of stone or slag ballast upon which the ties rest. It is easily handled by the shovel, does not heave much under the action of frost, and prevents weeds from growing. A good layer of cinders will much facilitate maintenance with a wet roadbed and earth ballast in the spring or in wet weather, when the earth is too soft to support the loads and cannot be tamped. In very bad cases the mud holes or wet spots may be dug out and filled with cinders. The cinders should not be laid on earth ballast when the frost is coming out of the ground, or this action will be checked, and it will be late in the season before it is thoroughly out. In cross-section, this ballast is sometimes formed the same as for broken stone, being shouldered out 6 ins., but more generally it is sloped like gravel. It is very generally used for sidetracks and yards. On a sidetrack it may either be sloped down to form a drain between that and the main track, or it may be filled in level with the latter.

Sand.—This makes a fairly good ballast under light traffic, but unless it is very coarse it requires constant attention and considerable maintenance work and renewal. The sand flows from under the ties as they move up and down under the traffic, is gradually drifted away by the wind, and is washed away by the rain. It is generally shaped the same as gravel, but if made level with the tops of the ties, and well shouldered out beyond them, it will hold the track better, and there will be less flowing from under the ties. Clean sand will drain well enough if shaped thus. Owing to its lightness and instability it does not keep track well in alinement. It is liable to heave. It also makes a very dusty track, and is thus very hard on journals and machinery, but good results may be obtained by oiling the surface. In France and India, sand ballast is often covered with a layer of broken stone or broken brick to prevent strong winds from blowing it away. Special grasses or bushes may be used as wind breaks in sandy districts, as has been done extensively on the Siberian Ry. and to some extent on the Old Colony Division of the New York, New Haven & Hartford Ry. (See "Oiling" and "Grasses" in Index.)

Earth.—Dirt, earth and mud are terms used for ballast composed of the natural soil along the line, which is the cheapest material to use but often the most troublesome and expensive to maintain. It is of variable quality, from sandy to clayey. Unless very sandy it cakes in hot weather, and if then disturbed by any work it becomes intolerably dusty. If well put up when dry, it will go through a wet season fairly well, but of course it cannot be handled when wet. It is liable to heave in the winter and to be washed by heavy rains. In continued wet seasons, or when the frost is coming out of the ground, it may

become so soft as to make it impossible to keep the track in safe condition, the ties churning the saturated material into mud. In such a case, good results may be obtained by digging out the mud and filling in with cinders (as noted under Cinder Ballast), or sometimes sods, brush or coarse grass are packed under the ties. To keep the track in anything like good condition, thorough drainage is necessary. The ballast is usually filled in 1 to 4 ins. over the ties at the middle, and sloped sharply to the bottom at the ends, passing clear under the rail, and continuing on the same or a flatter slope to the edge of the ditch or bank. A flat slope will carry the water off more quickly than a curved cross-section, and if the earth is at all above the bottom of the ties at the ends it is liable to form a pocket which will hold water and turn the ballast into mud. The roadbed should be thoroughly consolidated, so as to separate it from the earth ballast as far as possible, and thus assist drainage. On some lines in the Argentine Republic, which are ballasted with black loam, the surface is carefully formed and sloped in planes to drain rapidly to longitudinal and transverse channels, while grass is allowed to grow over the surface.

Miscellaneous.—Oyster shells are used on some lines along the coast; the ballast is good for light traffic, but does not hold the track under heavy traffic. Chert is a finely disintegrated stone, used mainly in the South, and for branch lines. It usually contains clay, and so resembles cementing gravel. Chats are the rock tailings from lead and zinc mills; the material resembles coarse sand, with ¼-in. particles. Disintegrated granite resembles clean gravel, except that the stones are angular instead of rounded. It is found in the Rocky Mountains. When blasted and handled by steam shovels, it breaks up to about the size of peas, but the stones are sharp and angular. It is easily handled, becomes very compact, makes little dust, and sheds water well. The weight is about 3,000 lbs. per cu. yd. The cost on the Union Pacific Ry. is 23.32 cts. per cu. yd., exclusive of haul; on cars at pit, 9.19 cts.; unloading from dump cars and putting under track, 13.37 cts.; tools, engineering and maintenance, 0.76 cts.

Ballast Cross-section.—There is a tendency to uniformity in shaping the ballast, using one form for different kinds of ballast instead of varying it with each material. The principal variation is for material that does not drain well. The American Railway Engineering Association recommends a practically uniform section for all ordinary material: Slope of ½ in. per ft. from center to end of tie; then a curve of 4 ft. radius, and a slope of 1 on 3 (1 on 1½ for stone) to the roadbed. For cementing gravel and chert, however, the curve is from beneath base of rail to bottom of tie, leaving the end of the tie entirely free. Several forms of cross-section have been described and illustrated in this and preceding chapters. The ballast must be shaped according to the standard sections, and these sections properly maintained. The toe should be neatly lined, and may be marked with pieces or stones of over 2½ ins. in size, if the ballast contains enough of such material. Large boulders must not be allowed in the ballast, but may be raked out and piled for use in washes or at ends of bridges.

Oiling Ballast.—Dusty ballast is objectionable both in regard to wear of the journals and machinery, and to the comfort of passengers. The latter is especially the case in summer, when the trains are almost enveloped in a cloud of dust or sand. While the use of stone and other dustless ballast is being extended, it will be a long while before its use is universal. The dust nuisance has been dealt with, however, on many roads by sprinkling the ballast with oil. This plan was first used in 1896 on the West Jersey & Seashore Ry. It

not only provides for the comfort of passengers, but also reduces the chances of hot boxes, kills or tends to check the growth of weeds, and reduces the heaving action of frost. With very fine sand, the dust will still fly, but not to such an extent as before oiling. The oil used is a residuum of crude petroleum, having a high fire test, low gravity, and only a faint smell. The first application requires about 2,000 gals. per mile of single track, and about 500 to 600 gals. per mile per year will suffice to keep the ballast dustless after tie renewals, etc. It was thought that after a year or two no further sprinkling would be required, but this is found not to be the case. The sprinkling is done from a flat car fitted with a 2-in. pipe across the rails and a 2-in. swinging pipe on each side, these pipes having slots $\frac{1}{16} \times 3$ ins. on the under side. With the side pipes swung out, a width of 14 to 20 ft. of roadbed can be sprinkled. The rails are protected by shields. The regulating valves and the swinging pipes are all controlled by levers or handles on the car. The sprinkler pipes are connected to a 4-in. main coupled to a tank car in the rear, and this train is pushed by a locomotive at a speed of 3 to 4 miles an hour. For oiling sandy cuts and roadbed see chapter on "Drainage and Ditching."

CHAPTER 4.—TIES AND TIE-PLATES.

The importance of the question of the source of supply for ties is shown by the fact that with an average of 2,700 ties per mile, the 300,000 miles of track in the United States represent 810,000.000 ties. The annual consumption is about 75,000,000 ties for renewals and 15,000,000 ties for new construction. If electric railways are included the total may well be over 100,000,000 ties, representing about 500,000,000 cu. ft. of forest grown material. This requires the annual culling of the best timber from about 1,250,000 acres (averaging 80 ties per acre), and the annual product of some 50,000,000 acres of forest, or about 10% of the forest area of the country. Many sources of supply have been practically depleted, and where local sources are exhausted the railways must use inferior local ties or obtain good ties from distant sources. The problems of the supply, durability and cost of ties are therefore being forced upon the attention of the railways. The reckless use, waste and destruction of timber in this country, and the utter disregard of economic principles, have been reprehensible features for years, and still continue. The government has made some advance in the protection of the remaining resources, but only the merest beginning has been made in the way of reforestation by railways or others. The Pennsylvania Ry. has plantations aggregating about 1,000 acres planted with black locust, chestnut, tamarack, pin oak, red oak and Scotch pine for ties (ready to cut in 30 to 40 years); also catalpa and locust for fence posts (15 to 20 years). The red oak and pine were selected with a view to their more rapid growth than white oak, while if treated and protected by tie-plates they will give about twice the life of untreated white-oak ties. These plantations, however, are too limited to appreciably increase the sources of supply.

Wooden ties will continue to be generally used in this country for many years, but great economy in their use can be effected, to the benefit of the railways and the timber resources. The use of preservative processes to prevent decay,

and of metal tie-plates to prevent wear and disintegration (and consequent rotting) at the rail seats, results in an increased life of ties and a reduced expense for renewals. It also gives a better and more permanent track, requiring less work for maintenance. The wider adoption of such preservative and protective methods is to be strongly advocated, since ties of cheaper and inferior timbers may thus be made equal or superior to those of the better species in both cost and durability. The use of a better rail fastening than the common spike would also tend to increase the life of ties. Further than this, there is a possibility of introducing some more permanent system of track construction, especially in tunnels and for city street and rapid-transit railways, as already noted. There is no economy in using inferior ties simply because they are cheap. The cost of placing is the same, they give worse service and require more frequent attention, and the maintenance and renewals therefore cost more; while the frequent disturbance of track and ballast by renewals makes it almost impossible to maintain good track. Greater care in inspection for renewals, so as to insure that the ties give their full effective life, will result in better track being maintained at reduced cost. An important economy resulting from the use of good ties and of methods for increasing their life, is the lessened disturbance of the track, thus permitting the ties to come to a solid bearing in the ballast and to remain upon it.

The principal timbers for ties are used in about the following proportions: Oak, 50%; pine, 23%; cedar, 9%; chestnut, 5%; tamarack, 4%; cypress, 3%; hemlock, 2%; redwood, 1%; red fir, 1%; larch and spruce, 1%; various woods, 1%. Included as various woods are red gum, black locust, elm, hickory and red cedar; also beech, maple and birch, but these last represent less than 0.1%. Those adopted for use with and without treatment are as follows: Untreated: white oak family, long-leaf pine, cypress (except white), redwood, white cedar, chestnut, catalpa, locust (except honey), walnut, black cherry. Treated: red oak family, pines (except long-leaf), tamarack, hemlock, spruce, red fir, black and sweet gum, beech, birch, rock and red elm, hard maple, and hickory. Red oaks, gum, beech and other inferior timbers contain much water, and check or split badly by rapid drying before treatment and the drying out of water-solution preservatives. They should be closely piled before and after treatment to reduce the rapidity of drying, and laid in track with heart side down. Checking may be prevented by driving S-shaped pieces of hoop iron into the ends, as is done in Europe. The treated ties showing checks are not so liable to split by spiking as is often assumed.

White oak (which is the species most largely used) is the best wood for ties not treated, in regard to both wear and durability. It is very hard, and is slow to rot, generally failing by decay rather than wear. Its average life is about 8 years under heavy traffic, though it sometimes lasts 10 or 12 years. Burr or rock oak and chestnut oak are next in value, lasting about 6 to 10 years, and are largely used for switch timbers. Pin oak is a medium quality. Black, red and yellow oak (which names are often used indiscriminately) are decidedly inferior species, lasting only about 4 or 5 years. Water oak lasts only about 4 years. Oak ties usually decay first in the part bedded in the ballast.

Pine is very largely used in its numerous varieties, of which yellow and white pine are the best, as, although they (especially the latter) are soft, they are slow to decay, and last from 5 to 7 years under heavy traffic or 7 to 9 years under light traffic. Long-leaf heart pine in the South will last 7 to 8 or even 12 years;

loblolly pine not more than 4 or 5 years, even with tie-plates. Southern pitch pine will last about 5 years in the South and 7 in the North. The checking of pitch pine ties is a serious defect, as the checks not only loosen the spikes, but allow moisture to penetrate the interior of the tie. Short-leaf yellow pine from Georgia, Florida and South Carolina will last 4 to 5 years. This very much resembles the Baltic fir extensively used for ties in Europe, but the latter is harder, being grown in a colder country. The objections to tapped pine (or timber from which the turpentine has been drawn) on the ground of impaired strength and inferior quality, have not been sustained by experience. Some specifications exclude long-leaf pine grown north of South Carolina. Most of such timber having already been cut, it is doubtful if it can be obtained in quantity, and the chance of substitution is therefore greater, especially as in a lot of southern pine few inspectors can distinguish the species. Yellow pine is very extensively used, but will decay in about 6 years, though it will resist wear for 10 years or more. It is often preferred to oak for bridge ties, as it does not warp. Spruce pine is used to a small extent, and is said to be more durable than Pennsylvania oak, while holding spikes better than chestnut. Of the pine used, about 75% is southern yellow pine, 20% western yellow pine (Rocky Mountain and Pacific regions), and 5% white and Norway pine.

Chestnut is equal to oak in point of durability. White chestnut may last 10 years on tangents and under light traffic, but with heavy traffic it cuts under the rails. The ties have a tendency to split, and they usually decay first in the part above the ballast. Cedar is very durable. Red and white cedar will last from 9 to 12 or even 15 years, but with heavy traffic will cut under the rails unless protected by tie-plates. Being soft they do not hold the spikes well on curves, and they fail by wear rather than by decay. Hemlock is, as a rule, neither hard nor durable, and its life is very variable, from 4 to 8 years. It is extensively used on account of its cheapness, but is not good for first-class track, as it gets soft under the rails and at the spike holes. Spruce is about the same, lasting from 5 to 9 years. Tamarack is very commonly used, and will last from 5 to 8 years. Both tamarack and hemlock are being more generally used since the introduction of tie-plates. Black and red cypress are much used in the South, where there is an abundant supply. It is soft, but the heart cypress is very durable, lasting 9 to 12 years (or more) if protected by metal tie-plates. Sap cypress is inferior. Redwood is extremely durable but soft; it cuts badly under the rails unless protected. Its ordinary life on the Southern Pacific Ry. is from 5 years upward, depending upon the traffic; it will last 12 years with tie-plates, and some specimens of black redwood (the best quality) last over 20 years if properly protected. It is only used in the Pacific states.

Black and yellow locust (which are quick-growing) are good but scarce. They are about as hard as oak, and have a life of about 7 to 10 years. Honey locust is about the same, but softer. Black walnut and catalpa are used to a limited extent, and last about 8 years. The latter is another quick-growing timber, but its value for ties is disputed. All these are available only in small quantities. Beech is hard, but very poor unless treated, having a life of only 4 to 6 years. Elm and cherry are fairly hard, and will last 4 to 8 years, but cherry has a tendency to split in spiking. Maple, hickory, ash, birch, butternut and white beech are used to some extent, but are of little value unless treated. They are rarely used except from local supplies on new construction. Soft

maple is of little use even if treated. Sycamore is brittle, and white elm too soft for ties. Sassafras, mesquite and mulberry are used to a small extent.

The use of Australian hardwoods has been suggested, but is only practicable to a limited extent. One of the best is jarrah (eucalyptus marginata); this is often confused with karri (eucalyptus diversicolor), which has less than half its life and is subject to dry rot. Jarrah is obtained mainly in western Australia; it is preferably hewed, to avoid cross-grained ties. In that colony it lasts 15 or 20 years, and fails by spike killing and rail wear; its local cost is 45 to 60 cts. In South Australia it costs $1.25 delivered, and many local timbers are used which are equally good but limited in supply. In Queensland it is not grown or used, and the ties are of native timbers (17 to 18 years) and ironbark (20 to 30 years). In New South Wales the ties are principally of red gum (20 years, life); this holds the spikes with very little redriving. In all these woods the spike holes are bored. Some so-called jarrah ties tried on the Mexican Southern Ry. failed in 5 to 10 years, due to improper species or to the moist climate. Jarrah may be distinguished from karri by burning a piece; the former leaves a black ash and the latter a white ash.

Pole ties and slab ties have the faces hewed or sawed (respectively), and the sides left round. A half-round tie is the same but wider on the bottom than the top. Heart ties must have not more than 1 in. of sap wood on the corners, measured diagonally across the end of the tie. For inferior lines and sidetracks, second-class ties are used. Culls are inferior ties, not generally accepted under specifications. Ties made from trees of such size that only one tie can be made from a section are termed pole ties; when two or more ties can be made, they are termed split ties.

The life of ties varies very considerably, and the apparent variation is exaggerated by lax systems of inspection for renewal and the lack of system in keeping records of the ties. This is discussed further on. The actual life varies in different sections of the country and on different railways, owing to the dissimilar qualities of timber of the same species grown in different parts, and to the influence of the varying conditions of climate, roadbed and traffic. Ties in sidetracks should not be included in estimating or averaging the life of ties. Ties on curves generally fail by the respiking and by cutting under the rail, so that they have to be taken out (as the gage cannot be maintained) perhaps two or three years sooner than similar ties on tangents. Ties usually last longer in good, well-drained ballast. Where ties are continuously obtained from one district, their life becomes less as the timbers' resources become picked over. Specific information as to the life of ties on individual railways is given in the tables of standard track construction at the end of this book, and may be generally summarized as in Table No. 2, but the figures are necessarily approximations, for reasons already stated.

TABLE NO. 2.—LIFE OF TIES (UNTREATED).

Oak	6 to 12; ave. 8	Locust (black or honey)	7 to 10
White oak	9 to 12	Spruce	6 to 8
Post oak	6 to 10	Red spruce	6 to 9
Rock or burr oak	8 to 10	Fir (Douglas)	4 to 8
Chestnut oak	8 to 9	Tamarack	4 to 8
Red or black oak	4 to 5	Hemlock	5 to 8
Pine	6 to 8	Catalpa	8 to 12*
Heart pine	8 to 16	Walnut (black)	8 to 10
Yellow pine	6 to 8; 9 to 11*	Cherry	6 to 8
Chestnut	5 to 9	Sassafras	5 to 8
Cedar	5 to 7; 12 to 15*	Hackberry	4
Cypress	5 to 9; 9 to 12*	Redwood	5; 12*
Black cypress	10 to 12		

* With tie-plates.

The idea that ties of old coarse timber are more liable to decay than those of young timber is not of general application. Young wood is the more apt to decay, owing to its larger proportion of albuminates, which form the food of the fungi. It is sometimes assumed to be more tough and fibrous, and therefore better fitted to resist decay, but as the sapwood of such ties becomes rotten in a few years, the size is reduced so that they are apt to be renewed without regard to the soundness of the heart. Sound, mature and well grown trees yield more durable timber than either very young or very old trees. In hard woods, trees of rapid growth (indicated by broad annual rings), due to favorable conditions of soil and light, yield the most durable timber. Second-growth timber of proper age and quality should in general be equal to first growth. In coniferous woods, however, trees of slow growth (indicated by narrow rings) yield the better timber. The most durable timber for ties, therefore, is furnished by coniferous woods from comparatively poor soils, high altitudes and dense forest; and by hard woods from rich, deep, warm soils and open forest. In all cases within the same species, the heavier and denser wood is the more durable, and the heart wood is, of course, more durable than the sap wood. Winter is usually the best time for felling tie timber, especially if it is to be used without being seasoned, as it then contains less fermentable sap, and seasons more slowly and evenly before the temperature is warm enough to cause rot. The timber may rot with or without fermentation, but usually without. Trees cut while in the leaf, as in the case of chestnut oak cut in May or June for tanbark, should be left for two or three months before being cut to size. In the South, pine is often cut during the summer, for which there is no apparent good reason. Timber cut when the sap is at rest is more durable than that cut when the sap is moving, mainly because fungus growth is less active in the former case. In the West there are large tracts of fire-killed timber which, owing to dry climate and high elevation, is still quite sound. This is available for ties, as the strength has not been impaired while the durability has been often increased. In some cases these ties have lasted longer than ties of green timber in the same track.

The importance of seasoning ties before use is not as generally recognized or practiced as it should be, although this practice is almost universally followed in Europe and accounts to some extent for the greater durability of the ties. Ties which are properly piled and left to season for six months or a year are far more durable than those put at once into the track. The ties should be barked and piled in rows of 8 to 12, spaced 4 to 6 ins. apart. In moist climates alternate rows should be separated by two ties at right angles to them. In very hot and dry climates the two end ties of each row may be set on edge, thus giving closer spacing. The pile should rest upon poles or blocking, as if laid directly upon the ground the fungus growth will soon attack the lower rows. Crib piles have four ties in each row. The ties of the top row should be placed close together, and inclined so as to shed water. The piles should contain 50 to 100 ties each, and be at least 5 ft. apart to allow an inspector to examine and mark the ties. If piled near the track, they should be at least 7 ft. from the rail, and, if possible, on ground higher than the rails. Ties should not be piled in damp places in the woods where cut, but in dry, airy and shady places. It has been said that seasoning may be expedited by sinking the ties in running water, but experiments indicate that this has but little such effect, and not enough to warrant the extra trouble. On the Atchison, Topeka & Santa Fé Ry., ties cut in June had lost 33% of their weight in the first 30 days, and only 1.6% more in the

next 90 days. Ties cut in December were stacked for six months before the loss in weight amounted to 33%, and after the first month there was practically no further reduction until warm weather. Large timbers, as for switch ties, headblocks, bridge stringers, etc., should be seasoned under cover, as otherwise the sun may cause them to season irregularly and to check or warp. Ties treated by water solutions should be seasoned after treatment until thoroughly dry, before being put in service.

Hewed ties are very generally assumed to be superior to sawed ties, and this has led to a custom of insisting that ties must be cut from trees that will make but one tie each, or to insist that the cut shall make but one tie. A 15-in. timber 16 ft. long will make only two hewed ties, but it will make four sawed ties, with lumber as a side product. The economic advantages of sawing are apparent. Two reasons are given why sawed ties are apt to decay more rapidly: (1) They present increased end surfaces of the grain, as the cut cannot be kept parallel with the fibre (especially when the log is not quite straight); (2) The saw does not make a sharp smooth cut, but leaves a more or less woolly surface, which permits the accumulation of water and affords opportunity for fungus growth. The second objection may be overcome by the use of a planer saw, which cuts and planes the surface. On the other hand, the axe marks or score marks on hewed ties permit the lodgment of water. Tie hewing or dressing machines are in use to a small extent. Sawed ties are being more and more used, and if treated by preservative processes the above objections are eliminated. Opinions and experience vary as to their use, and some roads require them to be 1 in. wider than hewed ties. The Baltimore & Ohio Ry. specifies 7 ins. for pole ties, 8 ins. for split ties, and 9 ins. for sawed ties. In 1905, 77½% of all the ties purchased were hewed, but of those purchased on the Pacific slope and the Rocky Mountain region 80% and 35% respectively were sawed. Ties sawed on four sides are used at switches and on bridges. The objections to split ties have largely disappeared, except as to the quick and deep season checking, which takes place in a split tie having the heart on one side. This side should always be laid downward. In Europe, S-shaped pieces of hoop iron are driven into the ends of checked ties to prevent the checks from widening. Warped, twisted and crooked ties should not be used, as they are liable to rock in the ballast. The bark should invariably be stripped off, or it will hold water against the tie. When it becomes loose it is very unsightly and interferes with proper tamping; it also allows the track to shift, the ties slipping against the smooth surface.

Ties should be made from sound, thrifty, live or green timber, free from loose or rotten knots, worm holes, dry rot, wind shakes, splits or other imperfections which affect their strength or durability. They should have no sapwood on either face, and not more than 1 in. on the edges or corners. They should be hewed or sawed with the faces perfectly true and parallel, should be of the specified thickness, the faces out of wind, smooth and free from any inequality of surface, deep or bad score marks, or splinters, and should be not more than 3 ins. out of straight in any direction. They should be of uniform size, and those of the same kind should be kept together as far as possible, to insure approximate uniformity in wear. The specifications should be carefully and intelligently prepared, and their requirements strictly enforced. Inspectors should reject all ties which are not of the required quality or dimensions, and should be sustained in this by their superior officers. Accepted ties should be distinctly marked with paint by the inspectors.

There are two principal elements governing the life of a tie: (1) Its resistance to decay; (2) Its resistance to the wear resulting from the cutting and abrading action of the rail. The direct compression under the rail is too slight to enter into consideration. Ties are rendered unserviceable by three principal causes: (1) Mechanical disintegration and abrasion under the rails caused by the slight motion of the rail on the tie; (2) Injury by spiking and respiking; (3) Natural decay, induced by fungus growths. Under ordinary conditions ties have to be renewed largely on account of the cutting and abrasion (and consequent local decay) at the rails. On the New York Central Ry. it was estimated that 20% of the ties taken out were removed on account of this class of injury, from 10 to 15% being reported as "crushed or broomed," and from 4 to 10% as "cut out" by respiking. This injury may be reduced by adopting improved rail fastenings to hold the rails and ties more firmly together. It may be almost entirely eliminated by the use of suitable metal tie-plates, which thus effect a decided economy in making ties of the softer and cheaper woods equally as serviceable as the harder and more expensive. Ties will wear out more quickly on curves on account of the lateral strain on the rails forcing the spikes back, enlarging the spike holes and reducing the frictional hold of the spike in the tie. They also wear out more quickly on heavy grades where the engines use sand. In both these cases metal tie-plates will aid materially to prevent the cutting and maintain the track in good condition.

The natural decay of the tie as a whole depends largely upon the wood, ballast, climate, etc. It usually begins at the ends and is much hastened by season checking, though this might be prevented by painting the ends with a cheap composition, so as to cause a slower exchange of moisture. Boring the holes for the spikes, as noted in the chapter on "Rail Fastenings," would prevent much of the checking, and if the size of the hole is proportioned to that of the spike it should increase the holding power. Ties should never be moved by sticking picks into them, as such practice forms places where decay may start. In some cases the ties have the rail seats "spotted" or leveled off by machine. This is very generally done in Europe, the rail seat being inclined so as to be parallel with the conical face of the wheel tires. The inclination or coning of the wheel tread is 1 in 20 both in England and in this country. The same machine may bore the spike holes. In facing the rail seats, whether by hand or by machine, it is not desirable to cut a depression in the tie. As a rule the machines are installed in a shop, but the Atchison, Topeka & Santa Fé Ry. has proposed to have a portable machine that can be moved from pile to pile in the storage yard and can face about 300 ties per hour.

Specifications for ties, as used by four railways, are given herewith, in abstract:

1. New York Central Ry.—Yellow-pine ties must be of good southern long-leaf yellow-pine timber, grown south of North Carolina, straight and free from rotten or loose knots, worm holes, shakes and other injurious imperfections. Faces parallel and free from deep score marks, splinters and other inequalities of surface. Well hewed on four sides; ends sawed square. No sap allowed, except 1 in. at the corners (measured on the face); the majority must show less than this. Variation not more than ½ in. in thickness and 1 in. in length. Class A, 7 ins. thick, not under 9 or over 10 ins. wide, 8 ft. long; Class B, not less than 8 ins. wide; Class C, 6 ins. thick, 9 to 10 ins. wide; Class D, 6 ins. thick, 8 to 9 ins. wide. Sawed ties accepted only under special arrangement.—Yellow-cedar ties must be hewed or sawed on two sides, with faces true and parallel; sawed

square at the ends. Hewed ties are preferred. Only one tie may be made from a section of a tree. Dimensions: 6 to 7 ins. thick, 6 to 12 ins. wide; average width 8 ins., and not more than 5% with the 6-in. minimum width.

Local ties must be of white or burr oak and chestnut; timber felled between Aug. 1 and April 1. Class A (pole): 7 ins. thick, 7 to 12 ins. wide, hewed on two parallel sides; only one tie from a section of a tree. Class B: sawed on two sides. Class C: sawed on four sides or split and hewed top and bottom to 7×9 ins.; two or more ties from one section of a tree. Class D: 6 to 7 ins. thick, face not less than 6 ins. at any point (not more than 15% with this minimum); hewed or sawed on two sides. Switch ties of yellow pine or white or burr oak (as above); sawed on four sides, square edged (pine not showing sap on any corner more than ¼ width of face); sawed square at both ends to specified length.

2. Delaware, Lackawanna & Western Ry.—Local cross ties and switch timbers must be made from green or living white or rock oak or second-growth chestnut of good quality; straight and free from decayed knots, wind shakes or other imperfections, and stripped of the bark. Hewed or sawed to sizes given; ends cut square. All ties 8 ft. 6 ins. long. All timber must be felled between Aug. 1 and March 1; except that rock oak may be felled at other seasons, provided it is peeled promptly after being cut. All inferior oak ties (red, black and pin) are considered third class. First-class ties are flatted or two-side ties with not less than 7-in. nor more than 12-in. faces; uniform thickness, 7 ins. Square or four-side ties must have 9-in. faces on two sides and a uniform thickness of 7 ins. Second-class ties are those not good enough or large enough for first-class. Flatted or two-side ties not less than 6 ins. thick with 6-in. faces will be accepted. Square or four-side ties must have 8-in. faces on two sides and a uniform thickness of 6 ins.

Yellow-pine ties must be of original growth, untapped, southern long-leaf variety, grown south of North Carolina. Hewed on four sides; 7-in. uniform thickness; faces not more than 10 or less than 9 ins. wide. Ends cut square. On each corner will be allowed 1 in. of sap, measured across the face. White- or yellow-cedar ties must be hewed or sawed smooth on two sides; uniform thickness, 7 ins.; width on face not more than 12 nor less than 7 ins.

3. Nashville, Chattanooga & St. Louis Ry.—Ties of sound white-oak, post-oak or chestnut-oak timber, well and smoothly hewed or sawed to proper dimensions, and saw-butted to exact length. Pole ties (made from one cut of the tree) must have top and bottom faces parallel, and the bark taken off. Sawed or split ties (with more than one tie made from one cut of the tree) must have top and bottom faces parallel. Split ties must be neatly counterhewed on all four sides, and have square corners. Sawed ties must be made from straight-grained timber. All ties 8½ ft. long, 7 ins. thick, and have a face of not less than 8 ins. for hewed and 9 ins. for sawed ties.

4. Cincinnati, New Orleans & Texas Pacific Ry.—Ties must be cut from green or living long-leaf, close-grained, yellow pine, or white-, post- or chestnut-oak timber, of good quality; free from twists, cracks, decayed knots, worm-eaten timber, or any unsound parts, and hewed or sawed square at each end. All tie timber should be cut between the months of October and February. The ties must be made from a single section of a tree, and must be hewed or slabbed straight and true, parallel with the grain of the wood and on two parallel sides only, and stripped of bark. Ties with sawed faces may be accepted as first class. They must be 8½ ft. long, 7 ins. thick, and have 9 to 12 ins. heart face. A variation of only ½ in. in length and ½ in. in thickness will be allowed. Split ties of above dimensions and specifications may be accepted as first class. Pole ties 7 ins. thick and with not less than 7 ins. of heart face, otherwise as above described, will be accepted as second class. Ties culled from first and second class to be third class, and to be taken at the option of the inspector.

The size and spacing of ties should be considered in relation to each other, and to the roadbed and traffic conditions. Smaller ties may resist decay better than large ties; and with tie-plates to prevent cutting, such ties may advisedly be

used. A large number of ties of medium width is better than a smaller number of wider ties in making an easy riding track. The thickness varies from 6 to 8 ins., but should never be less than 6 ins., or the spike may cause a crack in the bottom, besides which the deeper tie has greater stiffness to resist transverse bending. In view of present heavy loads and traffic, 7 ins. should be used in main tracks. The width is from 6 to 10 (or even 12) ins., but 8 ins. is a very good width for supporting the rail and bedding in the ballast. Where there is much difference, the wider ones may be used for joint and shoulder ties. Very wide ties are awkward to handle and tamp, require too much digging in renewals, and are liable to rock in the ballast. The necessity of uniform size has already been referred to, to form an easy riding track and to reduce the disturbance of the ballast bed in renewals. If the thickness is not uniform, then in renewals the tie-beds will have to be dug out or filled in, thus disturbing the stability of the track. The length varies from 8 to 10 ft., the latter being used (mainly in swampy districts) on some parts of the Southern Pacific Ry., Louisville & Nashville Ry., etc. The usual lengths are 8 ft. and 8½ ft., and for ordinary track it is doubtful if an increase beyond the latter is of much real use. Ties 9 ft. long should not be less than 7 ins. thick. The length should be uniform, for it is easy to cut the ties to the right length, and this will be done if the inspector insists upon it. Where it is not uniform, the ends should be lined on one side of the track. To facilitate this, a notch should be cut in the handle of a spike maul at the proper distance (varying with the width of rail base and length of tie); in placing the tie, the end of the handle is placed against the outer edge of the rail and the tie pushed in till its end is at the notch. Ties 3 ins. shorter than standard should be reserved for sidetracks.

There is little use in specifying uniform standard sizes for general use, as the sizes accepted will in each case be determined largely by the cost and available supply, and by conditions of track and traffic rather than by theoretical conditions. A list of adopted sizes is given in the tables of standard track construction at the end of the book. The two most general sizes are 6×8 ins.×8 ft., and 7×9 ins.×8½ ft. The 7-in. thickness is much to be preferred for main track, on account of the greater stiffness and the less liability of splitting the bottom with long spikes. Other sizes are 7×7 ins., 7×8 ins., and 7×9 ins.; with lengths of 8, 8½ or 9 ft.

The spacing of ties varies with the size and traffic, and ranges from 2,640 to 3,200 per mile, or from 14 to 18 per 30-ft. rail, but there should not be less than 16 per rail in main track. The practice is usually 16 or 18 ties per 30-ft. rail, or 18 to 20 per 33-ft. rail. On sidings, the number is from 2,400 to 2,800 per mile. The number should not be reduced as heavier rails are introduced, for the track as a whole has a certain deflection (in addition to the deflection of the rails), so that reducing the number of bearing points only serves to increase this deflection. This point is often overlooked in European practice. The deflection for a given rail and load varies practically as the cube of the tie spacing. Therefore, if we take 1 as the deflection between ties 20 ins. c. to c., the deflection for ties spaced 24, 30 and 36 ins. c. to c. will be 1.73, 3.38 and 5.83 respectively. The Pennsylvania Ry. uses 16 ties per 33-ft. rail on main track, and 14 for sidings and yards; the Illinois Central Ry., 18 for 30-ft. and 20 for 33-ft. rails; the Atchison, Topeka & Santa Fé Ry., 18 ties for 33-ft. rails on tangents, 19 and 20 on curves up to and over 3° respectively; the Chicago & Northwestern Ry., 18 to 21 per 33-ft. rail on tangents, and 19 to 20 on curves, depending upon the sizes of the

ties. The New York Central Ry. uses 18 and 20 ties to rails 30 and 33 ft. long; with the three-tie joints, the joint ties are 14½ ins. c. to c. (5 ins. clear) and the intermediate ties 24¾ and 21½ ins. for 18 and 20 ties respectively. Where this road has suspended joints, there are 16 ties per 33-ft. rail, spaced 17½ ins. at joints and 25¾ ins. for intermediate ties. On running sidings and storage sidings there are 16 and 14 ties, respectively, to a 30-ft. rail. The joint and shoulder ties should be somewhat closer together than the intermediates, so as to give increased bearing towards the rail ends, where the tendency to deflection is greater. The intermediate ties may be 16 to 24 ins. and joint ties 16 to 20 ins. c. to c. (8 to 10 ins. clear). Some consider that less than 10 ins. clear spacing does not allow of proper tamping, but this is not generally accepted, and at three-tie joints the clear spacing is 5 ins. on the New York Central Ry. and 10 ins. on the Illinois Central Ry. Some roads having light rails with heavy traffic space the ties by the width of a shovel, without regard to any fixed number of ties per rail, it being considered that on such tracks about 50% of the rail should be supported. The Michigan Central Ry. proposes to specify a variable number of ties, so that the rail will be supported for a certain percentage of its length. A few roads specify a certain length of tie-bearing per rail (130 ins. on the Duluth & Iron Range Ry.), or a fixed clear spacing, regardless of width of tie. This is not necessary where ties of uniform width are supplied, but is adapted to roads where hewed ties of varying width are accepted to prevent waste and to utilize local supplies. The numbers of ties per mile of single track with different spacing are as follows, but many roads lay one or two extra ties per rail on curves:

Number of ties per mile	2,640	2,816	2,992	3,168	3,344
Number of ties per 30-ft. rail	15	16	17	18	19
Spacing c. to c.	24	22.5	21.2	20	19

Longitudinals.—Longitudinal timbers are used to some extent in Europe, mainly on bridges and in tunnels or for rapid-transit underground railways. In such cases they have a solid bearing on concrete or steel, and are rarely laid in ballast. They were used on the old tubular Victoria Bridge of the Grand Trunk Ry. at Montreal and the old Long Bridge of the Pennsylvania Ry. at Washington, but the new superstructures have the ordinary type of floor. In the Broad St. station of the Pennsylvania Ry., at Philadelphia, the rails rest upon wooden blocks 2 ins. thick (19 blocks to a rail, but omitted at the joints), placed on longitudinal timbers resting on 11 cross-ties to each rail length; there is a tie under each joint, and the stone ballast is filled in level with the tops of the ties. In the Louisville & Nashville Ry. station at Louisville, longitudinal timbers 12×12 ins. were laid on cross-ties, and covered with continuous iron plates upon which were placed the 80-lb. rails. The new Pittsburg station of the Wabash Ry. has the rails laid on longitudinals 7×14 ins., which rest on ties 8×10 ins., 23 ft. long. These ties are laid across the top chords of plate girders, and are spaced 30 ins. apart. A 3×2-in. angle is laid on each edge of the longitudinal, and beneath it fits a curved rubber flashing which rests on the ties, the floor draining to longitudinal and transverse troughs of ⅛-in. sheet steel, with 4-in. down pipes.

Steel longitudinals have been extensively used in Germany and Austria, but are now largely superseded by steel ties. In Germany there were about 6,000 miles of main track with these longitudinals in 1889, and 500 miles in 1900. It has been found difficult to keep the longitudinals fully and uniformly tamped, and this, in connection with the wave movement of rails (especially light rails)

upon the continuous steel bearing, produced wear of both longitudinal and rail. It has been supposed that lighter rails could be successfully employed for the continuous supports, but this is not borne out by experience. The Duff trough-shaped longitudinals of pressed steel were used on a spur of the Pennsylvania Lines at Leetsdale, Pa., in 1904, and the Lindenthal built-up steel longitudinals (but with intermittent supports for the rails) were tried on the Pennsylvania Ry. in 1906. Concrete longitudinals have been proposed, and have been actually used in the inclined shaft of a mine. (See Chapter 1.)

Blocks or Compound Ties.—Many designs have been made for ties composed of separate blocks connected by a transverse steel member. Pairs of metal bowls with steel tie-bars are largely used in India and South America, and pairs of concrete blocks permanently connected by tie-bars have been tried in this country. With wooden blocks, the purpose is to use only 50 to 60% of the metal for a steel tie and to utilize good pieces of wood which are not long enough for ties. Ties of this kind were used in Holland in 1882, the blocks being the sound portions of old ties, laid in the ends of a steel channel. The Paris, Lyons & Mediterranean Ry. (France) has tried a compound tie having two wooden blocks 27.5 ins. wide and 5.3 ins. thick placed in an inverted trough of 0.20 in. steel, 7.2 ft. long, 5.5 ins. deep, 5.12 ins. wide on top and 8.66 ins. over the bottom ribs (7.87 ins. inside). Four cross bars with hooked ends were clamped across the bottom, holding the blocks in place and preventing the sides from spreading. A cheaper design has blocks 5.12 ins. thick and 8 ins. wide placed between 4-in. channels having the narrow ribs outward and connected by cross clamps. There is a through bolt at each block. The blocks project above the channels and carry tie-plates. The results were very promising as to strength and efficiency. A similar design has been tried on the Chicago & Northwestern Ry.; the 5-in. channels are 8 ft. long and placed with the flanges inward; between them are wood blocks 24 ins. long, 8 ins. wide, 6 ins. high, projecting ½-in. above the channels and fitted with tie-plates. Ballast is filled in between the channels. The Chicago & Western Indiana Ry. has tried a few ties consisting of two creosoted blocks $6\times8\times36$ ins., grooved on top to receive the web of a steel tee bar $5\times1\frac{1}{2}$ ins. Owing to the Carnegie I-beam steel tie being considered too rigid for high-speed main tracks on the Lake Shore & Michigan Southern Ry., Mr. Buhrer (the designer) has invented a compound tie. An 8½-ft. steel tee, 9 ins. wide and 4½ ins. high (or a bulb angle $8\times5\frac{1}{2}$ ins.), carries two blocks of white oak or treated red oak, $16\times7\times8$ ins., slotted at the bottom to fit over the web of the tee bar. Two straps or stirrups pass under the bar and up the sides of the blocks, fitting notches in the bar and being bolted through the blocks. One advantage claimed for ties of this class is that they cannot become center-bound by tamping the ballast too hard at the middle. (See also "Concrete Ties.")

Tie Renewals.

The tie renewals are too frequently considered by executive officers as a comparatively unimportant item in the expense account of maintenance of way. They fail to appreciate the expenses involved, which include the cost of all labor for removing the old and putting in the new ties. As a consequence of this, tie expenses are continually increasing, while much of the general maintenance expense for labor can be charged to the deterioration of track due to the softening of ties from incipient decay, and to the more frequent renewals of ties. The cost of putting a tie in the track is estimated at 20 to 50% of its first cost. On

the Erie Ry. the cost of labor has been estimated at 9 to 14½ cts. per tie; on the Southern Ry., 10 cts. is considered a fair average for labor, including removal, replacing and tamping. On the Pennsylvania Lines, 20 cts. in stone and 11 cts. in gravel; the Chicago, Milwaukee & St. Paul Ry., 8 and 10 cts. respectively; and the Chicago & Alton Ry., 20 cts. in stone ballast.

Tie renewals average about 250 to 350 ties per mile per year for main tracks, and 200 to 250 for sidetracks, but these figures may be considerably reduced by the use of preservative processes and metal tie-plates. The average number of tie renewals per year per mile of main track on some leading railways has been as follows: Pennsylvania Lines, 179 to 273 (average 228); Chicago & Northwestern Ry., 280; Chicago & Alton Ry., 300 (200 in sidetracks), without tie-plates; Illinois Central Ry., 300; Louisville & Nashville Ry., 360. The Southern Ry. reports 330 with first-class oak ties and 500 to 600 with inferior oak, according to ballast and drainage; on side lines with first-class oak ties the number is less than 300. It will readily be seen that a road which has to renew its ties every 5 or 6 years is at a disadvantage as compared with one whose ties last 10 years or more. The former must not only figure into its expense account almost double the cost for material and track labor, but must consider the additional amount of disturbance for renewals.

The average cost of tie renewals is now considerably in excess of that of rail renewals, and shows a tendency to increase, for the following reasons: (1) Increase in price of ties, owing to the increased value of timber as the supply is diminished, and to the increased haul as the sources of supply become more distant; (2) the use of the best timber for other purposes, so that the poorer qualities must be cut for ties; (3) less rigid inspection and the acceptance of inferior ties; (4) increased tendency to cutting and decay under the rails, due to increased wheel loads and traffic; (5) spike killing, caused by regaging, redriving loosened spikes, etc., which also is due to increased wheel loads and traffic.

Ties have a most irregular life, even when cut at the same time from the same locality, and as the annual renewals average from 225 to 350 per mile, there is probably hardly a rail length of main track which has not at least one tie renewed each year. The cost involved includes the first cost of the new tie, the labor cost of renewal, and probably the cost of some new spikes. Some of the ties from main track are good for sidings, fence posts, etc. Others, unless available for fuel, are valueless, so that there is no credit for "value of old material." If any of the old spikes are bent or broken in pulling, they are as likely to be thrown away as to be sent to the scrap pile, thus involving another incidental expense. It is practically impossible to get the new tie at once as well and firmly bedded as the old one, which has probably been cut into by the rail so as to reduce its thickness. When the new tie is in place, therefore, it may be either tight (raising the rail slightly above its normal surface) or loose (allowing the rail to deflect before the tie gives it proper support).

If we consider such conditions as occurring once in each rail length of track, it will be seen that a certain increase in wear of rails and wheels, and in the motion of cars, must result. These effects will continue until the traffic (pounding from above) and the section men (tamping from below) have restored the normal surface of the track, as far as may be in view of the increased wear which has been sustained. By the use of metal tie-plates, and treated ties of longer and more uniform life, all this expense and work may be required only at long intervals, and individual renewals will be much less frequent. Under such con-

ditions there would be a saving in operating expenses, distributed partly in the roadway department and partly in the transportation department. This is one of the advantages resulting from the use of steel ties. The renewal of all ties on a stretch of track has been tried in some cases, but is generally by "spotting," or putting in ties here and there as required. The lack of uniformity in the supporting power of individual ties is one of the weak points of the track structure, and is one reason for the proposed use of longitudinal I-beams under the ends of the ties, as noted in Chapter 1. The whole track would then be raised or surfaced as a unit.

Close attention should be paid to requisitions for ties. If they are granted too liberally or without due inspection, there will be a tendency among the foremen to take out ties before they have given their proper service. If they are habitually cut down below proper requirements, there will be many ties left too long in the track. A marked saving in renewals may be effected by systematized checks and the preparation of careful estimates of each season's requirements. In this respect practice varies very widely, some roads being very careful and others careless. The section foreman should determine by actual count, and not by a guess estimate, the number of ties on each mile of his section, which he considers will need to be renewed. This will be reported to the roadmaster, who should personally verify the estimate on a mile here and there in company with the foreman, so as to educate him, for while ties are often left in too long, yet many foremen condemn ties which are still good. On the Chicago & Northwestern Ry., each foreman marks with an axe the ties which he thinks should be removed, after which the roadmasters go over their divisions to check the foreman's judgment, and they generally cut down the estimates very considerably. On the Southern Pacific Ry., the roadmasters prepare the requisitions in June, after a personal examination of the track. On some roads, the foremen are forbidden to remove ties having more than 4 ins. of good timber left under the rail. Broken ties must of course be removed at once. Ties should not be renewed without orders, and those taken out should be piled by the track and not destroyed or removed until after inspection, so that good ties may not be wasted.

On the Illinois Central Ry. the practice is as follows: The supervisors (in charge of about 100 miles) walk the track with their section foremen and make a memorandum of the number of ties in each mile that in their judgment needs renewal. The reports (showing the number for each mile) then go to the roadmasters (with 225 to 486 miles), the superintendents, the general superintendent, and the engineer of maintenance of way. The roadmasters and superintendents take the reports and personally walk over individual miles to check the judgment of the officers below them. The engineer of maintenance of way and the general superintendent also pick out certain miles, walking the track and counting the ties, in order to check the judgment of the division officers. In preparing the final requisition, these reports are considered, together with the normal renewals for a period of ten years, the number of ties removed, and the general judgment as to the necessity for these renewals. This system has an important influence in educating all the officers who work under it, and in affecting an economy in tie renewals. After the old ties have been taken out, in the spring, they are piled up and inspected by the officers concerned before they are destroyed or used for any purpose. In some cases the selection is taken out of the hands of the roadmasters. On the Baltimore & Ohio Ry.

this is done by the tie inspectors, who walk over the track and make a mark with white paint on the tie and the web of the rail. These inspectors also examine the ties after removal. In general, however, the practice is as already described, the roadmasters preparing the estimates and submitting them to the superintendent, chief engineer, or engineer of maintenance of way, according to the organization.

Records and Marking.—Very few railways have kept systematic or reliable records from which the average life and cost of ties of different kinds under different conditions of soil, climate and traffic can be computed. Without such records, the calculations and estimates of comparative durability and economy of different ties (treated and untreated) are little more than guess work. The Atchison, Topeka & Santa Fé Ry. has established a tie and timber department, having charge of purchase, treating, records, etc. A uniform and carefully formulated system of records should be kept by the roadmasters or officers of similar position. The record should include the cause of tie renewals (decay or rail cutting), and should keep ties in sidetracks separate from those in main track. As a rule, the only statistics of untreated ties show the number purchased in a given time or the number removed on a certain length of line, without regard to the wood, the ballast, or other influential conditions. And even such statistics are not kept in a uniform manner. With the more general use of treated ties the importance of keeping a reliable and uniform system of records has begun to be recognized, and the American Railway Engineering Association has a standard form of record blank for this purpose which is being adopted on a number of railways. This record should be kept for each division separately, since if it were made to cover the entire railway it would be too vague to be of any use. The real difficulty, however, is to get exact and accurate statements from the section foremen who actually handle the ties, and if their reports are not complete and accurate the statistics are of little value. In renewing treated ties, the foreman should report on special blanks the number put in and taken out each day, with cause of renewal and date of stamp on removed tie. A dating nail should be driven into each new tie as soon as it is placed on the track. The information given in tie records above noted should include the following:

Information for Tie Records.

1. Length of division.
2. Length of all main track.
3. Average number of ties per mile.
4. Average number of ties renewed per mile.
5. Per cent. of renewals to number in track.
6. Total number of ties renewed.
7. Kinds of timber used.
8. Number of each kind renewed.
9. Cost of new ties in track.
10. Place where new ties were obtained.
11. Date when the old ties were laid.
12. Main track curved; per cent.
13. Main track tie-plated; per cent.
14. Number of tie-plates per rail.
15. Kind and depth of ballast.
16. Weight of rail.
17. Treated ties; per cent of total in track.
18. Preservative system employed.
19. Average cost of treated ties at distributing point.
20. Average cost of untreated ties at distributing point.
21. Average life of treated ties.
22. Average life of untreated ties.
23. Total cost of tie renewals per mile of main track.
24. Gross tonnage of traffic per annum.
25. Maximum weight of locomotive.
26. Ties renewed in sidetrack; number.
27. Ties renewed in sidetrack; per cent.
28. Number of old main track ties put in sidetrack.

It is desirable to mark both treated and untreated ties to indicate the date when they were placed in the track, so that their life can be ascertained. This is very rarely done with untreated ties, and except for the uncertain memory of a foreman or roadmaster, there is no means of ascertaining the life or history of ties in the track. One method is to mark each tie as it is put in the track by

cutting a small V-notch in the edge, the position of the notch indicating the year. Another method is to mark the tie by means of a 3½-lb. stamping hammer or a die struck with a sledge. The hammer or die has one or two figures about 1½ ins. long, ⅛-in. in relief, indicating the year. This is now little used, as in a very few years the marks are illegible. The best method is to use a dating nail, and this is now the general practice where treated ties are used. It is a ¼-in. galvanized nail, 2½ ins. long, with a ⅝-in. circular head having the last two figures of the year stamped in it. These are supplied to the foremen, who mark each tie when it is placed in the track. They report monthly the number of ties removed, the cause of removal, and the date the ties were laid. From these reports the records are compiled.

Old Ties.—Ties which are taken out and are not good even for sidetracks may be used for fence posts, for cribbing in wet slopes and on construction work (as in track elevation), or for various incidental purposes. They are usually burned on the right of way or used for fuel at roundhouses, etc. They should not be destroyed or disposed of until inspected, as already noted. Old ties and bridge timbers intended for fuel may be economically cut up by a shearing machine having the upper (moving) blade set about 1 in. out of line from the lower (fixed) blade, thus allowing old spikes or bolts to pass through without injuring the knives. The machine will cut timbers 8×16 ins., and has an attachment with knives by which the wood is split lengthwise to the size desired. They may be cut to length by a circular saw, and then split by a 500-lb. drop hammer operated by a vertical air cylinder 6×48 ins. The Chicago & Western Indiana Ry. uses a cutting and splitting machine whose knives are operated by two air cylinders. Where ties have been burned or cut, the ashes or chips should be raked over for old iron, which has an intrinsic value in the scrap heap. They should not be burned too near the track, or the heat may injure the varnish on cars.

Tie Plugs.—These are used to fill old spike holes, whether spikes are to be driven in the same place or not. It is usually economical to use machine-made plugs. Elm is the most satisfactory wood.

Preservative Processes.

An extensive development in the use of treated ties and the establishment of tie-treating plants has taken place during the past few years, with a view to securing a more permanent track with reduced expenses for ties and maintenance of way. The long neglect of this important matter, in the face of long and extended experience in foreign countries, has been due largely to the failure to properly appreciate the economics of the tie supply question, with a consequent disinclination to incur initial outlay to obtain permanent economy. The number of tie and timber-preserving plants has increased from about 15 in 1900 to 33 in 1904 (12 being then operated by railways), and 50 in 1907. In 1905, about 7,500,000 ties were treated, or nearly 10% of all the ties purchased. There is now ample evidence as to the efficiency of the preservative processes and the economies resulting from their use in this country. While a first-class tie would be somewhat expensive when treated, yet the use of preservative processes enables cheaper and (if untreated) inferior timbers to be used at about the same cost as (or even less cost than) untreated ties of a more expensive timber. Thus, mountain-pine ties that last only about 4 to 5 years, and sap-pine ties that last only 2 to 3 years, have been proved to last from 10 to 12 years and from 7 to 10 years, respectively, when treated. The same applies to many other species of

timber in greater or less degree. As an example of the results, the Southern Pacific Ry. found that by the use of burnetized ties since 1887, the tie renewals were reduced from 243 per mile of track (including sidings) in 1891, to 240 in 1892, 203 in 1893, and 145 in 1894. Most of the progress in the use of treated ties has been made on western railways.

On roads where a fairly good quality of timber is used for treating, the economy will be in the maintenance expenses rather than in the cost of the ties. But where good ties are expensive and the available ties are poor, there may also be a very material saving in the first cost of the ties. To arrive at any definite conclusion in regard to the advisability of using treated ties on any particular railway, it is necessary to carefully and thoroughly consider the relations of expenses for ties and tie renewals and track work, and the cost and life of treated and untreated ties under the conditions of location and traffic of that road.

In most of the processes, the principle of the treatment is to extract the sap and replace it (under pressure in a closed vessel) by a material which will fill the cells of the wood and prevent fermentation and decay. The timber should be thoroughly seasoned before treatment, and the ties should be allowed to stand for some weeks after treatment, before being put in the track, in order to allow the chemicals to become permanently settled in the wood. It is waste of time and money to hurriedly treat fresh timber for immediate use, though this is sometimes done, owing to contracts for ties not being placed in time. With certain kinds of inferior woods, however, decay begins so soon that long seasoning may not be practicable. Some close-grained woods (such as Oregon red fir) are also best treated green because the pitchy sap coagulates in seasoning and so prevents the entrance of the preservative. The ties for seasoning should be stacked in the storage yard, and marked with the date on which they were received.

The preservatives mainly used are creosote oil and zinc-chloride. The former is the more effective, but the more expensive, although processes are being introduced which are designed to render it more economical, as described below. Pine ties that last only 3 to 5 years when untreated will last from 8 to 12 years when impregnated with zinc-chloride. A creosote treatment might give 25 to 50% longer life, but (with ordinary methods) at 3 or 4 times the cost. Mechanical destruction by spike wear and rail wear might easily prevent the realization of the extra life. For either system the ties are treated in a horizontal cylinder or retort, 6 to 8 ft. diameter and 120 to 200 ft. long, with a narrow gage track inside. Each charge should be composed of ties of the same kind and about the same age, to insure a uniform result. Each car or buggy load of ties should be weighed as it passes in and again as it passes out of the cylinder, and any load showing an insufficient amount of absorption should be treated again. Whatever process is used, it is essential that it should be carried out carefully and thoroughly, if the best results are to be obtained. For this reason, among others, several large railway companies prefer to operate their own plants, which plan is likely to give satisfactory and economical results if the work is carried on systematically. The details must vary with wood, climatic conditions, ballast, etc.; also with different uses, as for ties, piles, poles, bridge timbers, etc. A few railways have portable plants which are operated on sidetracks near the source of supply, thus reducing the amount of transportation.

One stage of the treatment has been the steaming of the wood in the cylinder to soften the cell walls, and dissolve the contents of the cells; the sap and moisture

are then caused to flow out by creating a vacuum. The advisability of this is now disputed, especially for ties to be treated with oil, as the moisture in the tie (due to condensed steam) tends to resist the entrance of the oil. For such material, the practice in Europe is to thoroughly air-season (or artificially dry) the ties, and to omit the steaming, the first stage being to create the vacuum. Another plan is to boil the ties in the creosote oil (charged hot) so as to evaporate the sap. In this case the cylinder is filled with oil, and a temperature of 230° to 240° F. is maintained for from 6 to 12 hours, depending upon the size of the timber and the extent to which it has been air-seasoned. After this "oil seasoning," the oil is cooled below the vaporizing point of water, and the water and sap are drained off from the upper part of the cylinder. Pressure is then applied to force the creosote into the wood. When mineral-salt preservatives are used, made into solutions with water, the steaming is not objectionable, as the solution will readily mix with any moisture in the tie. A light steaming may be employed with timber that has not been well seasoned, such as timber that would begin to decay before properly seasoned. In any case, care must be taken not to carry a high steam pressure, or the wood will suffer injury. The safe maximum is 20 lbs., except that in the case of very wet timber it may be as high as 30 lbs., but only at the beginning.

Creosoting.—This process consists in impregnating the timber with creosote oil or dead oil of coal tar. It is very extensively used abroad, but its introduction in this country has been hindered by the higher cost of creosote oil, and the consequent expense of the treated ties. It is the best process from a chemical point of view, and methods for employing it in more economical quantities or in combination with a cheaper medium are being tried. The stages of the process in the closed cylinder are essentially as follows: (1) Exhausting the air; (2) heating the ties by steam to soften the cell walls and dissolve the contents of the cells, (3) creating a vacuum to draw the sap out of the wood, and (4) filling the cylinder with hot creosote oil and applying pressure to force it into the wood. The creosote is heated to make it sufficiently fluid to thoroughly penetrate the wood. The first and second stages may be omitted under certain conditions, as noted above. If steaming is employed, the cylinder should have an open vent, and steam should be blown off before the second vacuum is created. After the oil has been drained out of the cylinder, a light vacuum may be created to draw off oil near the surface, leaving the wood clean and dry. The ties should be well seasoned, as a wet tie will absorb but little oil, while a thoroughly dry tie will readily absorb a large quantity which, when solidified, is not affected by moisture in the air or ground. The oil should be thoroughly forced in, and, if possible, any cutting, framing or boring should be done before the tie is treated. The absorption is about 8 to 12 lbs., or 1 to 1½ gals. of creosote per cu. ft. of timber. In France, it is from 11 to 15 lbs. for oak, 25 to 30 lbs. for pine, and 28 to 50 lbs. for beech. Creosoting sometimes softens the wood, and renders it more easily cut by the rail. This effect is only temporary, and if the ties are stacked for about six weeks after treatment, no trouble is likely to be experienced.

The oil is obtained by the distillation of coal tar. One of its principal preservative constituents is naphthalene; in this country and France this is 10 to 25%; in England only 6 to 8%. It melts only at about 175° F., and if liquefied during the treatment it penetrates the wood cells and then becomes solidified and permanently fixed. Acridine and anthracene are important constituents and also remain permanently, protecting the timber from decay and from boring

animals. The tar acids, which were formerly supposed to induce coagulation of the albumen in the tie, and thereby to be the principal preservatives, are found to disappear in a comparatively short time. The character of the oil in any case will depend somewhat upon the use to which the wood is to be put. This quality depends upon the method of manufacture, and the character of by-products extracted. Where carbolic acid or naphthalene are recovered, the creosote oil will be low in tar acids and naphthalene respectively. In this country, it usually contains a large amount of naphthalene, and very small amounts of phenol (carbolic acid) or cresol. There is practically no anthracene, as the temperature required to distill this from the tar would result in a hard pitch, while soft pitch is desired, being in great demand for roofing purposes. Thus American creosote oils are of varying character and of varying efficiency as preservatives. Much of the creosote for tie preservation is therefore now obtained from Europe. The specifications of the Atchison, Topeka & Santa Fé Ry. provide that the oil must have a specific gravity of not less than 1.03 at 100° F. as compared with water at 60°. It must be thoroughly liquid at 100° and remain so on cooling to 90°. Up to 340° nothing must come off by distillation, not more than 5% of its weight up to 410°, and not more than 35% up to 455°. Above 670° F. not more than 4% should remain as solid residuum. If there is more than 2% of water in the oil an additional amount of oil must be injected, but oil with more than 6% of water must not be used. The weight of the oil is about 8½ to 9 lbs. per gallon. Wood creosote oil, obtained by the destructive distillation of pine, has been tried but is not satisfactory. Its paraffine oils have been claimed to act as preservatives, but their value is very much questioned. One analysis is as follows: tar, 10%; tar acids, 36.7%; neutral oils (mostly paraffine oils), 53.3%.

A description of the methods employed in creosoting ties for the Cleveland, Cincinnati, Chicago & St. Louis Ry. is given in Engineering News, Sept. 13, 1906. The ties are of the red-oak family, hard maple, beech, hickory, ash and rock elm; they cost 35 cts., or 65 cts. when treated with 2½ gallons of oil per tie. It is thought that with tie-plates and screw spikes to reduce the mechanical injury to the wood, the ties might well last 12 or 16 years. The ties accepted for use without treatment cost from 65 to 75 cts., and have an average life of 9 years. On the Southern Pacific Ry., creosoting is used for timbers only, with the exception of ties for special work. The details of the process are identical with those of burnetizing (described farther on), except that the steaming period is from 4 to 12 hours, varying with the size and seasoned condition of the timber. The vacuum after steaming is maintained for 1 to 2 hours, when oil at 150° to 170° F. is admitted, the cylinder filling in 10 to 15 mins. The pressure is then applied, and maintained for 1 to 6 hours, varying with the size and condition of timber, and the amount of absorption required. The time consumed is 10 to 20 hours.

Burnetizing.—This process (or the zinc-chloride process) consists in impregnating the timber with a solution of metallic zinc in hydrochloric acid. If the solution contains free acid (which may exist in minute quantities and be unequally distributed through the solution) it will tend to make the timber brittle. To guard against this, slabs of metallic zinc may be kept in the storage tanks and the solution occasionally stirred, the zinc taking up the acid. In this country several million ties have been treated with a solution of 5° Baumé (3.9%), without making them brittle. The process is not considered adapted to stringers or bridge timbers. The quantity used must depend upon the character and

condition of the wood, the ballast, and also the climatic conditions, as the material is soluble and may be leached out. It should be at least 0.50 lb. per cu. ft. of timber, and more for damp locations. The Southern Pacific Ry. has used 0.30 to 0.50 lb.; the Union Pacific Ry., 0.40 lb.; and the Great Northern Ry., 1 lb. At the Las Vegas plant of the Atchison, Topeka & Santa Fé Ry., the solution is about 1 lb. of chloride to 4 gals. of water, and the dry chloride injected is about 0.50 lb. per cu. ft. of timber. The ties treated at this plant cost 25 cts. and have an average life of nearly 12 years. The records of 13,700,000 burnetized ties on this railway's lines east of Albuquerque, N. M., show an average life of 10.62 years for those removed for decay. The Illinois Central Ry. has found that newly treated ties are of such greatly increased conductivity that for some time they cause trouble with the rail circuits of the signal system. Red-oak ties treated by this process are sometimes badly checked, which may be reduced by piling the ties closely while seasoning before and after treatment, to prevent rapid drying out, being held for at least 4 weeks after treatment. To prevent checking while in the track, the ties should be laid with the heart side down. The checking tendency may also be prevented by driving S-irons (above mentioned) into the ends of the ties before treatment or in treated ties as soon as received by the railway.

On the Southern Pacific Ry., burnetizing is used only for ties and loblolly sap pine. The treatment is such as to get an absorption of ½-lb. of pure zinc-chloride per cu. ft. of timber. Also to get the maximum amount of absorption of solution; that is, the weakest possible solution is used that will give the required absorption of zinc-chloride. The present operation requires a 1.15 to 1.20% solution. The ties absorb 2.4 to 2.6 gals. or from 20 to 22 lbs. per cu. ft. This gives an absorption by volume of about 33%, and by weight 30 to 50%. When the cylinder is closed, live steam is admitted, and the pressure rises to 20 or 25 lbs. in 30 to 50 min. Temperature, 240° to 250° F. During the steaming period, water of condensation is drawn off from the bottom of the cylinder. After 3½ to 4 hours, steam is blown off (25 to 40 mins.). The vacuum pump is started, and a 22-in. to 24-in. vacuum is produced, and maintained for 45 mins. to 1 hour; then a solution of zinc-chloride 1.2% strong and at a temperature of 100° to 130° F. is admitted, filling the cylinder in 8 to 10 mins. Pressure pumps are started, and the pressure carried up to 100 or 120 lbs., which is held until the required amount is absorbed. This takes from 45 to 90 mins., varying with the size and condition of the ties. The solution is then drawn off in 10 to 15 mins. The charge is removed and another charge is pulled in. Time consumed in treatment, 7 to 8 hours. Burnetized ties removed between 1894 and 1902 showed an average life of 9.25 years.

Wellhouse or Zinc-Tannin Process.—In wet or damp locations the zinc-chloride (being soluble) may be leached out by the dampness in the atmosphere and the ballast, and several auxiliary or combination processes have been introduced to seal the wood cells after the impregnation has been completed and thus retain the preservative medium. The best known of these is the Wellhouse or zinc-tannin process, which has been extensively applied in this country. The operations at the portable plant of the Chicago & Eastern Illinois Ry. (treating water, red and yellow oak) are as follows: The cylinder being closed, the air is exhausted by a pump, and live steam at 20 lbs. pressure is admitted for 3 hours, the interior temperature not being allowed to exceed 200° F. A vacuum is again maintained for 1 hour, to cause the sap to flow, the liquid being then drawn off.

The cylinder is then filled with a zinc-chloride solution of 3% to 4% strength, which is retained under 100 lbs. pressure for 2 hours or more. The cylinder is then emptied and filled with the gelatin solution; again emptied and filled with the tannin solution, both under 100 lbs. pressure for 1 hour. The absorption averages 31 lbs. per tie. By applying the three solutions separately, a much greater penetration and absorption are obtained, as the zinc solution (which is the preservative) is very fluid, while the other solutions (which are to close the cells) are thick and ropy, and penetrate but a short distance. Under the other method, glue is added to the zinc solution (2 lbs. per gallon), and the tannin solution is applied separately. The tannin and gelatin (or glue) combine to form a waterproof leathery substance which permanently closes the outer cells of the wood, excluding the damp and retaining the zinc. Of 1,250,000 ties laid by the above road from 1899 to 1906, only 6,087 were removed in the 7 years; many removals were due to changes in tracks, and only about 1,500 due to failure. Ties treated by this process are extensively used on the Chicago, Rock Island & Pacific Ry., which employed the two-injection system up to 1895, and then the three-injection system. The average life of the treated ties east and west of the Missouri River has been respectively 10.66 and 11.66 years. On the Pennsylvania Lines, the average life of burneti :ed hemlock ties has been 9.65 years for those removed, but is estimated at 10.68 years for those in the track.

Zinc-Creosote and Zinc-Gypsum Processes.—In the zinc-creosote process, as first employed in this country, the timber was impregnated with a 2% solution of chloride of zinc (12 lbs. of solution per cu. ft. of timber), and then with creosote (about 3 lbs. of oil per cu. ft.) in order to seal the outer cells. As used in Germany, a special quality of creosote oil is added to the zinc solution in the proportion of 4.4 lbs. of oil per tie, or 1.25 lbs. per cu. ft. of timber. This last method has also been used here, the creosote and chloride solution being mixed as an emulsion. The penetration (even in red oak) is said to be as good with the zinc-chloride solution alone, and as effective as the two-process zinc-tannin treatment. A zinc-gypsum process has been tried on a small scale.

Rueping Process.—This is designed to reduce the cost of treatment with expensive preservatives, by extracting that part which fills the wood cells, leaving the cell walls impregnated. It may be applied with either mineral-salt or oil preservatives, but is mainly used with the latter on account of the high cost of creosote oil. The timber in the treating cylinder is first subjected to an air pressure of from 60 to 70 lbs., compressing the air within the wood. The oil is then forced in under a higher pressure (75 to 85 lbs.), the air being given a vent without reducing the 65-lb. pressure. When the cylinder is full, the vent is closed and a pressure of 105 to 125 lbs. applied. When this is reduced (after the necessary time) the air compressed and confined in the wood cells expands, forcing out the oil from the cells while leaving the cell walls impregnated with the oil. The efficiency of a limited dose, however, remains to be proved, and the advisability of very high pressures is disputed. Compact or dense woods do not appear to respond well to this treatment. As a rule it is considered better to induce the entrance of oil by first creating a vacuum in the wood than to force it in under heavy pressure. As to the economy, it is said that 33% of the oil first put in will be driven out again, the wood being preserved with 4 to 5 lbs. of oil per cu. ft., as against 10 or 15 lbs. In the plant of the Atchison, Topeka & Santa Fé Ry. at Somerville, Tex., the proceedings are as follows: An air

pressure of 75 lbs. is created in the treating cylinder and in an overhead oil cylinder, which takes about 30 mins. The creosote is then allowed to flow by gravity into the treating cylinder (20 mins.). The pressure is slowly increased to 150 lbs. (in 1½ hours) and maintained for 15 mins. It is then released and the oil drained off, while the air in the wood cells, compressed to 150 lbs., forces out the surplus oil. To remove the oil around the outside pores, a 22-in. vacuum is gradually created in 1½ hours and then maintained for 15 mins. The oil thus removed is then drained off (10 mins.). Total time, 4 hrs. 20 mins. This plant has six treating cylinders 6×133 ft., and between and above each pair is a pressure cylinder 6×100 ft. for the oil. (Engineering News, May 3, 1906.)

Kyanizing Process.—The ties are steeped in open tanks in a solution of about 1 part of bichloride of mercury (corrosive sublimate) to 100 parts (by weight) of water; or 1 lb. to 8 or 10 gals. One day is allowed for each inch of thickness of the wood. Care is necessary, as the material is an active poison. It hardens the wood, but is generally more satisfactory for timber that is kept dry. The Boston & Maine Ry. used kyanized hemlock ties at one time, and found that the process paid when well done.

Thilmany Process.—The ties are impregnated under 80 to 100 lbs. pressure, with a solution of sulphate of zinc (or sulphate of copper, but this is more expensive), and then a solution of chloride of barium. These form a chemical combination of insoluble sulphate of baryta and chloride of zinc. It has only been used experimentally for ties, and unsatisfactory results were reported, owing apparently to the combination failing to take place thoroughly in the small wood cells.

Boucherie Process.—A solution of 1 lb. of sulphate of copper to 100 lbs. of water is applied, either in a cylinder or by a cap fitted to one end of a log or tie, the solution being forced through by pressure or vacuum. It would require about 80 to 100 hours for the solution to travel through a log as long as a tie. The rails and spikes decompose the solution, producing free sulphuric acid, which attacks the fibers of the wood. It has been used but little.

Vulcanizing Process.—The timber is placed in the cylinder and subjected to an air pressure of 100 to 175 lbs. at a temperature of 300° to 500° F. This was claimed to chemically change the sap into a preservative composition, but knowledge of the chemistry of wood does not sustain this claim, and tests made by the U. S. Forestry Bureau showed no increase in strength and no chemical or physical change. Tests have also shown that the temperatures claimed did not reach the interior of the tie. It is practically a seasoning process, and with resinous woods it may effect a more complete distribution of the resinous matter, which is of a preservative character. A subsequent treatment with creosote, formaldehyde and resin, and a final treatment with resinate of lime were afterwards proposed to make the process effective. The latest suggestion is to use a vacuum instead of pressure, removing the water in the sap, while the denser fluids retained are operated upon by the heat. It is said to be adapted for soft woods (pine, cypress and gum). Some experimental ties laid on the Erie Ry. were said to have lasted for 25 years.

Giussani Process.—This is for treatment in an open bath. The tie, fence post, pole, etc., is immersed for 1 to 4 hours in a bath of anthracene and pitch or heavy creosote oil heated to about 285° F., the boiling point being 400° F. The sap and moisture are thus believed to be boiled out and the air also expelled. The tie is then rapidly removed to a bath of cold creosote oil of lighter character,

where it remains for about 5 minutes, the vacuum due to expulsion of air and condensation of the enclosed vapor inducing a penetration of the oil. It is finally immersed for 2 or 3 hours in a bath of cold chloride of zinc. The process has been used in Italy. In this country, experiments with open-tank treatment have been made by the U. S. Forest Division, and it is considered as the result of experiments that the conditions should be as follows: (1) For green timber: temperature, not over 230° F.; 8 to 10 hours in the hot bath; 8 to 10 hours in the cold bath. (2) Seasoned timber: temperature, not more than 10° above the boiling-point of water; 3 to 6 hours in the hot bath, and 3 to 8 hours in the cold bath. The process is best adapted to woods of open texture, such as gum and the inferior species of pine.

Crude-Oil Process.—The Atchison, Topeka & Santa Fé Ry. has had promising results from the use of California crude oil, which has an asphalt residuum of about 77.5%, the balance being mainly light oils. Thoroughly air-seasoned ties were treated with this oil heated to 180° F. and forced in under 150 lbs. pressure. At that temperature most of the light oils had evaporated and the residuum was as fluid as creosote. The ties absorbed 4 to 7 gallons of oil each. They were laid where untreated loblolly and long-leaf pine ties last only 2 and 4 years respectively on account of heat and moisture, but after 5 years' service the treated ties were in first-class condition. It is not claimed to have any antiseptic properties, but to seal the wood cells and so exclude heat, air and moisture.

Miscellaneous.—Fernoline, spirittine, pinoline and woodiline are preparations resembling wood creosote oil. They are used either as a bath for ties, poles and timber, or as a paint for bridge and station timber, planking, piles, ferryboats and scows, etc., to prevent decay and the attacks of boring worms. The Pennsylvania Ry. wood preservative for such purposes is a distillate from Georgia pine. The specifications require 5% tarry matter (not over 12%), 45% tar acids (not less than 30%), 50% neutral oils; flashing point, 172° to 200° F.; burning point, 200° to 220° F.; running point, 15° to 20° F.; specific gravity, 1.03 to 1.05. The bath is usually heated to about 150° F. Carbolineum and other preservatives are used in a similar manner. Old spike holes may be filled with tar or refuse resin from turpentine distilleries, but the materials are awkward to handle. When piles (treated or untreated) are left with the heads exposed, as in the case of fender piles, the heads should be well coated with tar, which is better than creosote oil, as it forms a mechanical cover to exclude the moisture. On framed work for bridges, trestles, docks, etc., the framed portions may be well painted with some preservative before being put together, unless the timbers have been treated after framing. Poles for telegraph lines and electric railways may be treated by painting with or by boiling in preservatives. Material applied with a brush should be warm enough to be fluid, but should not exceed 200° F., or some of the oils will readily evaporate as the material is applied. The painting should cover a zone extending about 2 ft. above and 4 ft. below the ground line. In some cases the entire pole is treated in a closed tank or retort by the processes above described; experiments are being made by treating the butt end only, and in an open tank. The open tank may be of triangular section, the poles being laid on the inclined bottom. The preservative employed with this open-tank boiling process should contain practically no light oils, and the temperature should not exceed 275° F.

Metal Tie-Plates.

There is usually considerable trouble from the cutting of soft-wood ties by the rails, and this is aggravated by the resulting local rot under the rails and around the spike holes, and by the further wear and disintegration of the softened wood. The cutting also decreases the hold of the spikes, letting the rail drop loose below the spike head and allowing it to get out of gage and to tilt on curves. The direct pressure of the rail on the tie has little destructive effect, but it is the slight wave motion of the loose rail which causes the cutting, grinding and abrasion of the wood, and the wear or "necking" of the spikes. One of the most important of modern improvements in railway track is the use of metal tie-plates, placed between the rail and the tie. They involve only a small additional cost, but effect a most decided economy in ties and in track work. They act as a tie protector and are in no way to be classed with the chairs (obsolete in this country, but still extensively used abroad), whose office was to hold the rails in position. They are usually of steel, but the self-attaching tie-plate which becomes an integral part of the tie, independent of spikes, bolts, etc., is a distinctive feature of American railway track. The cheapness of tie-plates, combined with their advantages in efficiency and economy, has led to their very extensive use. They not only increase the life of ties of durable but soft timber (whether treated or untreated), but also effect a direct economy in renewals and maintenance of way. At the same time they add to the permanence and security of the track by giving a durable and uniform bearing to the rails, and lessening the disturbance of track for tie renewals. They prevent the widening of the gage which occurs (particularly on curves) by the tilting of the rail as the lateral pressure causes the outer edge of the rail base to cut into the wood. If accurately punched they also cause the spikes on both sides of the rail to act equally to resist the outward lateral pressure. On curves they have been successfully used instead of rail braces, as they resist the tendency to tilt the rail in the manner above described. On steep grades, the plates prevent the increased cutting of the ties due to sand from the engines getting under the rail and helping to abrade the wood.

Besides their use on open track (especially with soft ties and heavy traffic), tie-plates may be used with special advantage as follows: (1) At terminals and yards, where, on account of frequent switching and the use of sand, the rails cut into the ties very soon, while tie renewals are difficult and expensive, and interfere with traffic; (2) on hard ties on curves, to save the uneven wear of the rails and the loss of thickness in the ties by frequent adzing of the rail seats; also to save the frequent lining and respiking, and to maintain correct line and gage to insure easy riding curves; (3) at switch leads on main track, under the rails that cut into the long ties, thus saving expensive renewals of ties otherwise perfectly good; (4) at rail joints, to prevent the rail ends from deflecting by cutting into the ties; (5) on bridges and trestles. The plates may be used on every tie with soft wood. With good, hard ties they are sometimes used only at joints and quarter ties; or 6 to 10 plates to each rail.

Flat-Bottom Tie-Plates.—A flat plate is the simplest form, but it is impossible (with spike fastenings) to keep such a plate tight, so that there will be a continual movement of the rail on the plate and the plate on the tie, with a consequent admission of dirt and moisture to cause wear and decay. At the same

time, there will be a clattering under traffic, and thin plates will buckle. The New York elevated railways laid some flat plates 6×8 ins., $\frac{1}{4}$-in. thick, in 1888, but in addition to buckling and cracking at the ends, they induced premature decay of the yellow-pine ties, and were very noisy. The fear that flanged tie-plates would injure the wood fiber and also cause the entrance of moisture has at different times led to later experiments with flat plates, and some roads are using them extensively. As a general thing, however, there is little foundation for such objections, as the flanges compress the fibers tightly, while the base of the plate is in contact with the face of the tie and prevents water from working in. This has been shown in many cases where the wood under the plates has remained in good condition while the remainder of the tie decayed.

The flat tie-plates must of course, be made heavier, having no ribs or flanges to stiffen them. The St. Louis & San Francisco Ry. and the Chicago, Rock Island & Pacific Ry. have adopted a plate somewhat on European lines (Fig. 22). It is thick enough to prevent buckling, and has V-shaped bottom flanges only deep enough ($\frac{1}{8}$-in.) to indent the surface and prevent slipping. The plates are $8\frac{3}{4}$ ins. wide, $6\frac{1}{2}$ ins. lengthwise of the rail, with a thickness of $\frac{1}{2}$-in., tapering to $\frac{3}{16}$-in. at the edges. On the outer side of the rail seat is a $\frac{3}{16}$-in. shoulder. The plate has four spike holes. The Southern Pacific Ry. is using flat-bottom plates on treated ties. They are $8\times8\frac{1}{2}$ ins., $\frac{7}{16}$-in. thick for 5 ins. under the rail, and having a shoulder at the outer side. Some of them have two 1-in. channels $\frac{3}{16}$-in. deep in the face or rail seat to allow the escape of sand or dirt; this also reduces the weight. The Union Pacific Ry. and the Atchison, Topeka & Santa Fé Ry. have also used flat plates extensively in recent years, but have had difficulty in keeping them tight. On the latter road they are $8\frac{1}{4}\times6$ ins., with a thickness at the rail seat of 29/64 to 33/64-in. This variation gives a slight inward inclination to the rail. The plate has a shoulder for the rail. and four shallow grooves run along the rail seat. The rattling is most serious on soft-wood ties, and has been largely overcome by using three spikes; one of the inside spikes is so placed as to hold the plate in one direction, and does not touch the rail. It is proposed to try a different pattern of flat plate in connection with screw-spike fastenings. The Pennsylvania Lines are also using flat plates, but in connection with screw spikes. This is in accordance with European practice, the screw spikes being relied upon to hold the rail and plate rigidly to the tie. A shoulder on the plate takes the edge of the rail (or the splice bar). The thickness is $\frac{1}{2}$-in. (except directly under the rail, where it is reduced by a channel in the under side), and the plates are $9\frac{1}{4}\times6$ ins. for intermediate and 11×6 ins. for joint ties. The holes are 29/32-in. for the $\frac{3}{4}$-in. necks of the spikes.

Flange and Claw Tie-Plates.—To effectually attach the plate to the tie, various arrangements of flanges, spurs and teeth have been devised, to secure a firm hold and to do as little injury as possible to the wood. This appears to have been most efficiently attained by longitudinal flanges, which are forced into the wood and are tightly held by the fibers compressed between them. The flanges are of V section, and of such size as not to split or crush the wood, and they also serve to stiffen the plate. Long experience shows that the plates become immovably fixed upon the tie, do not cause checking or cracking, and do not cause decay. For plates with chisel-edged claws or spurs cutting across the grain, it is claimed that the grip is equal to that of four good spikes, but such plates must rely on their thickness for stiffness. The objection that outward thrust on the plate will force out the fibers cut by the spurs does not seem

reasonable, except with very soft and poor ties. The more serious objection is the direct cutting and severing of the fibers, and this also applies to tie-plates having flanges across the face of the tie.

Shoulder Plates.—Some plates are made with a rib or shoulder on top, in order to relieve the spike from the outward thrust of the rail and the wear due to abrasion by the edge of the rail base. This certainly seems reasonable when we consider the inefficiency of the spike as a fastening for rails under heavy traffic. There is also a tendency to use this form of plate to afford the rail extra resistance or support against lateral thrust, or excessive spike shear due to low coefficient of friction between rail and plate. The flat-top plates have in general been found satisfactory, and there has been little or no "necking" of the spikes, even on sharp curves, provided that the holes are so punched that the rail base is the full width between them and that there is not more than $\frac{1}{32}$-play between the back of spikes and plate. With screw spikes, the tie-plate should have ribs to give a bearing to the outer side of the spike head. This gives important resistance to displacement or distortion by lateral forces exerted on the rail head.

Dimensions of Tie-Plates.—The plates should be large enough to give a good bearing on the tie, with room for the spike holes, but if too large they will not allow for the wave motion of the rail and may cause the ties to rock in the ballast. Plates 5 and 6 ins. lengthwise of the rail, 8 or 9 ins. wide, are now most generally used, but flat plates the full width of the tie ($8 \times 8\frac{1}{2}$ ins.) are being used, as already noted. The thickness is from $\frac{5}{16}$-in. to $\frac{3}{8}$-in. for flanged plates, and up to $\frac{1}{2}$-in. for flat plates. The wear of the plate by the rail is slight, except in some exceptional cases, so that great thickness is not required to resist such wear. The depth over the flanges is about 1-in., as a maximum, or say $\frac{5}{8}$-in. under the plate.

Application of Tie-Plates.—The plates should be fully bedded into the ties in the first place, and not left to be driven home by the weight of the trains. The traffic will not do this uniformly or efficiently, and meanwhile there is a liability of gravel, etc., getting under the plates and preventing them from becoming properly bedded. The face of the tie must not be adzed more than is absolutely necessary to get a flat and even bearing. In setting these plates, the line side of the tie is marked and the plate put on at the proper distance from the edge. The other plate is then set in its proper position by a gage. The plates may be forced into the tie by machine, but the most general method is to use a sledge or wooden beetle of about 15 to 20 lbs., with a 36-in. handle. A wooden or metal block or follower is put on the plate to distribute the force of the blow. Unless this is done, a careless man may bring the edge of the maul upon the plate and buckle it. In applying plates to ties already in the track, the rail may be lifted and the plate slipped under. An iron plate is then placed on it, or one upon each projecting end, and the ends are struck simultaneously with mauls. One end of a flanged plate may be settled into the tie, and the free end then driven with a sledge, causing the flanges to plow their way through the wood under the rail. Special tools are used for setting the plates in right position. (See Tools, and Maintenance.) The Union Pacific Ry. at one time had a hand car fitted with a drop hammer (like a pile-driver) at each side. A saddle block was set astride the rail with its legs resting on the projecting ends of the plate, the plate being driven home by the drop hammer. A similar block may be used and struck with sledges. When plates are put on old ties a flat seat must be adzed or the ties may be turned.

Considerable economy in track work may be insured by setting the plates before the ties are distributed. In the construction of the San Francisco & San Joaquin Valley Ry. (A., T. & S. F. Ry.), the ties were unloaded in the material yard and put through a steam tie-plating machine, which gaged the plates and drove both plates home. Ties could then be stored, or shipped to the front and put into the track without a loss of plates. This method gave exceptional results as to cheapness and as to effective bedding of the plates. As the track was laid, the plates which came under joints were removed and joint tie-plates substituted at very small expense. Machines of this kind operated by steam or hydraulic power can be established at tie-treating plants or mounted on a car for use at division points where ties are stocked.

Shimming.—The self-attaching tie-plate is intended to be a permanent part of the tie, and no attempt should be made to remove the plate when shimming is required. The shims should be placed between the rail and the plate, being bored to correspond with the spike holes in the plates. Where shims more than 1½ ins. thick are required, a piece of plank should be spiked to the tie and the shims placed upon it. If the traffic is very heavy, a second tie-plate may be placed on the shim.

Examples of Tie-Plates.—The Servis flanged tie-plate (Fig. 18) was the first used to any practical extent. The Wolhaupter plate (Fig. 19) has longitudinal

Fig. 18.—Servis Tie-plate.

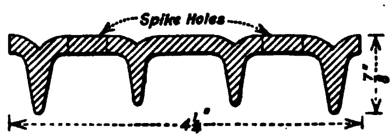


Fig. 19.—Wolhaupter Tie-plate.

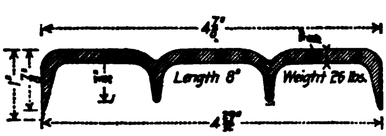


Fig. 20.—Q. & W. Tie-plate.

Fig. 21.—Goldie Tie-plate.

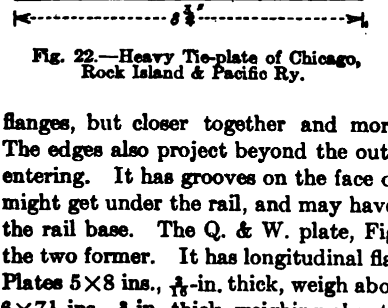


Fig. 22.—Heavy Tie-plate of Chicago, Rock Island & Pacific Ry.

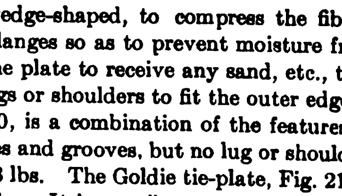


Fig. 23.—Post Tie-plate; Netherlands State Railways.

flanges, but closer together and more wedge-shaped, to compress the fibers. The edges also project beyond the outer flanges so as to prevent moisture from entering. It has grooves on the face of the plate to receive any sand, etc., that might get under the rail, and may have lugs or shoulders to fit the outer edge of the rail base. The Q. & W. plate, Fig. 20, is a combination of the features of the two former. It has longitudinal flanges and grooves, but no lug or shoulder. Plates 5×8 ins., $\frac{5}{16}$-in. thick, weigh about 3 lbs. The Goldie tie-plate, Fig. 21, is 6×7½ ins., ⅜-in. thick, weighing about 5 lbs. It has a rib on top, and at each corner is a flat chisel-edged or pointed lug which is driven into the tie, cutting

across the grain. There are other forms of tie-plates in use, all more or less closely resembling those above described. Fig. 22 shows the heavy plate adopted by the Chicago, Rock Island & Pacific Ry., and already mentioned In Europe, tie-plates or base plates are heavier than those generally used in this country, owing partly to the fact that they are not self-attaching but are held only by the rail spikes, screws or bolts. In the Post tie-plate, Fig. 23, the bottom is either flat (but with the maker's mark in relief) or has small sharp teeth to prevent slipping. It is 8×8½ ins., ½-in. to ⅝-in. thick under the rail. The outer edge of the rail base bears against a shoulder and is held by a screw spike; the inner edge is held by a clamp and screw spike. The Sandberg plate is

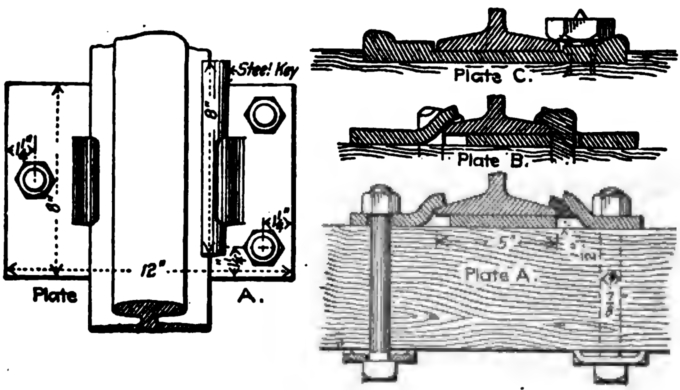


Fig. 24.—Sandberg's Tie-plates.

shown in Fig. 24, with three styles of fastenings. It is about 12×18 ins., ½-in. thick, weighing 13 lbs.

Wooden Tie-Plates.—These have been extensively and successfully used in France for several years. Those of the Eastern Ry. (France) are of hard wood, 8 ins. long, 5 ins. wide (the width of rail base) and ¼-in. thick. The ties have seats trimmed to receive the plates, which are held by the pressure of the screw spikes, but this cutting of a recessed seat is not advisable or necessary. The plates cost about $2 per 1,000 and last from 1 to 1½ years in main track. When worn out, the spikes are slackened, the old plate is pushed out, a new one inserted and the spikes again screwed home. Experiments in this country are also giving satisfactory results. The object is to prevent the disintegration and cutting of the tie by the rail, and while this has been effectively obtained by the steel tie-plates, the wooden plates are of course much cheaper. The Northern Pacific Ry., the St. Louis & San Francisco Ry. and the Atchison, Topeka & Santa Fé Ry. have used them on stretches of 40 to 50 miles of track. They are of red cypress, red gum, white and red oak, beech and elm; some are creosoted, but this is not considered necessary with hard woods. The plates are ⅜ to ½-in. thick, with a length equal to the width of tie, and a width equal to that of the rail base. The grain of the wood is lengthwise of the rail. The Cleveland, Cincinnati, Chicago & St. Louis Ry. has put in 100,000 creosoted beech tie-plates; each weighs about 0.4 lb. and costs 0.6 ct. (creosoted). The Gulf, Colorado & Santa Fé Ry. finds that they wear slightly and occasionally split, but they do not tend to cause the rails to creep. They are considered preferable to steel tie-plates for

roads of medium heavy traffic and equipment, for the reason that they are cheaper and the cost of application is nominal. They can be placed in track for 1 ct. per plate, or 2 cts. per tie. The plates which this road has been using are of cypress, birch, gum and elm. Plates which had been in track a year were found to have worn slightly, but were still good for two years. Some difficulty was experienced at first by reason of the plates slipping endwise from under the rails, and two small nails are now driven in the corners of the plate.

Metal Ties.

Metal ties have been used on a very extensive scale and with very satisfactory results in other countries, on main lines with heavy traffic, as well as for secondary lines and pioneer railways. They have as yet made but little progress here, owing to the hitherto abundant supply of cheap and good timber. With the decreasing quantity and quality and the increasing price of wooden ties, the steel tie becomes a consideration from an economic point of view. The few experiments made in this country up to 1905 were of little importance, and on too limited a scale to give any definite results. No reliable conclusions can be based on tests of a few ties, but at least a mile should be laid for experimental work. Since 1904, there has been an important development in this direction, due largely to the work of the engineers of the Carnegie Steel Co. in studying the matter with a view to the introduction of a rolled steel tie which would be successful in service and therefore open a new line of product for the steel mills. This is noted below. Metal ties are extensively used in Europe, India, Africa, South America and Mexico. Details of these ties and their service are given in the author's reports on "The Use of Metal Ties for Railways" (issued by the Forestry Division of the United States Government in 1890 and 1894). In 1894 there were 35,000 miles of railway laid with metal track, or 17½% of the total mileage of the world, exclusive of the United States and Canada. In 1907, Germany had 15,000 miles of track (33% of the railway system) laid with steel ties. The great majority of steel ties are in the form of a rolled or pressed trough or channel laid inverted in the ballast. This is developed from the type of tie invented by Vautherin, the French engineer, in 1864. It has the advantage of making a complete tie in one piece, without rivets or extra parts. Built-up ties are in general more expensive and less satisfactory. Cast-iron and cast-steel bowls and plates, connected in pairs by transverse tie-rods, are extensively used in India and South America. The latest pattern used in India weighs 230 lbs. complete, and renewals average only 0.6 to 0.8% per annum.

The advantages of metal ties are in longer life, reduced wear of rails, reduced cost and labor of maintenance, superiority of track, permanence of roadbed due to reduction in renewals and maintenance work, and a decided ultimate economy. Excellent and easy-riding track is made with good metal ties, but of the innumerable forms of ties which have been tried, only a comparatively small number have proved successful. The fastenings should be of as few parts as possible, giving good resistance to the lateral thrust of wheels, and providing for an adjustment of gage at curves, switches, etc. Some of the bolted clamp fastenings are found to remain tight and prevent rattling. To prevent noise due to the contact between the steel rail and tie, packings of felt, wood, asbestos, tarred canvas, etc., have been tried, but without much success, and there is little need of such packing with good fastenings that do not work loose. Where track circuits for automatic signals are used, insulating

plates must be placed under the rails, and washers and sleeves on the bolts The ends of the tie should be closed, to resist lateral motion, and the friction of the core of ballast thus enclosed over the bed of ballast greatly increases this resistance. Stone ballast about 1-in. in size is generally best for main tracks, although close-packing coarse gravel is sometimes preferred. Wooden ties are generally substituted at frogs and switches, but long steel ties can be (and are) used, affording extra security. Steel ties bent and distorted by derailment, etc., can often be made serviceable again by straightening in a hydraulic press, as is done where such ties are used extensively. Old steel ties also have a market value as scrap. The design and manufacture of the tie and fastenings should be such as to insure good material, strength and accuracy of fit; also to allow of the tamping, surfacing and lining of track. Bessemer, Thomas and Siemens-Martin steel is used abroad with about 0.1 to 0.2% carbon, and having a tensile strength of 50,000 to 60,000 lbs. per sq. in., with an elongation of 18 to 20% in 8 ins., and a reduction in area of 30 to 40% at the point of fracture. The ties for the New York Central Ry. were of soft steel, to stand pressing to shape; the steel had 0.1% carbon, 0.4% manganese, 0.081% phosphorus and 0.033% sulphur. Corrosion occurs in certain saline soils, in ashes, etc., and the ties are usually dipped hot in a bath of tar. Cracks are less likely to start from drilled than from punched holes. The tie should be of simple design, and with the smallest number of parts consistent with security and the necessary adjustment; the thickness should be sufficient for strength and wear, and the weight sufficient to hold the track down. From 120 to 175 lbs. is probably the best weight for a tie for first-class track carrying modern heavy engines and heavy rolling stock. Of the numerous designs of metal ties invented, few are of practical value, owing mainly to the failure of the inventors to comprehend or provide for conditions of service. Lightness and cheapness are too often aimed at, with the result of making the tie unserviceable and uneconomical; or in other cases the design is so unwieldy or complicated as to be impracticable for manufacture or use.

The life of steel ties will vary from 20 to 40 years, and even 50 years is claimed. For the first 2 to 4 years the labor and cost of maintenance will be about the same as, or perhaps more than, with wooden ties, the expense being mainly on the ballast and the rail fastenings. The metal track, however, then becomes permanently consolidated and the attention required for the fastenings and for maintenance of surface and line steadily decreases. With wooden ties, however, the work and expense continue to increase year by year, until renewals are necessary. One of the great advantages of metal track is that it is not disturbed frequently for tie renewals, and is thus kept in good condition for running. A part of the Netherlands State Railways (Holland), laid with Post steel ties and carrying 25 trains daily, was carefully tamped and put in condition, and was then left for 40 months without any other work than occasional tightening of the nuts.

American Steel Ties.—The Carnegie tie (Fig. 25) is a special rolled I-beam with wide flanges, as designed by Mr. Buhrer, of the Lake Shore & Michigan Southern Ry. While the trough type has been most generally adopted in steel-tie designs, I-beam ties were designed several years ago by a French engineer, Mr. Severac, and were extensively used. Those on the Northern Ry. (France) were 4.8 ins. deep and 3.2 ins. wide over both flanges; to the bottom was riveted a plate 9.6 ins. wide with the ends turned up against the

ends of the beam to form anchors. Rail chairs or seats were also riveted to the top flange. These ties weighed from 150 to 200 lbs. each. The Carnegie tie is similar, but with all rivets and extra parts eliminated, the rolled shape being a complete tie. The I-beam is 5½ ins. deep, with top and bottom flanges 4½ and 8 ins. wide. The length is 8 ft. 6 ins., and the weight 164½ lbs. (19.36 lbs. per ft.). At each rail seat are four holes 25/32-in. diameter, so spaced that two will carry the bolts at joints and two at intermediate points. The rail is secured by bolted clamps of such shape as to allow of ¼-in. change of gage for curves, wear of rails, etc. The ties can readily be supplied of any length for use as switch ties, and are used for this purpose on the Bessemer & Lake Erie Ry. Where track circuits are used, a ¼-in. fiber tie-plate is placed under the rail, and fiber bushing between the bolt and clamp. About 500,000 of these are in use on important railways and also on street railways. The Bessemer & Lake Erie Ry. has over 250,000 in main track (with 100-lb. rails and 8 ins. of slag ballast) carrying very heavy engines and traffic. The wear of the rails is reduced, and is more uniform. These ties are used in first construction and are also mixed in with wooden ties in renewals. On the Pittsburg & Lake Erie Ry., the ¾-in. bolts have button heads with the bearing face sloped to

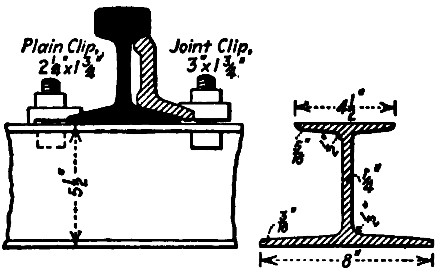


Fig. 25.—Carnegie Steel Tie.

fit the flange of the tie. The holes in the clamps are so placed that by reversing them and turning them upside down four widths of gage can be secured. Each rail rests on a ¼-in. fiber tie-plate 4½×12 ins., with holes for the bolts. In each bolt hole of the tie and clamp fits an insulating bushing with a flanged top; in this again fits a malleable-iron bushing of the same shape, the nut lock resting upon its top flange. A derailment on a stretch of track laid with these ties on the Pennsylvania Ry. in 1907 was not due to the ties, but some investigators considered that the damage to track was greater than if wooden ties had been used. But if track with rails bolted to steel ties is better than with rails spiked to wooden ties (as may be the case with proper design and construction), a possible liability to greater injury in case of derailment is no valid argument against it. Mr. Shand, Chief Engineer of the road, considers that the steel tie is the best substitute for wood and that its use will increase. It may be made heavier, and with improved fastenings, especially in regard to resisting the lateral thrust on the rail. There is, however, an impression that steel rails on steel ties make too rigid a track, and some steel ties with wooden blocks are now in use, as described under Compound Ties.

About 1,000 steel trough ties were laid on the Bessemer & Lake Erie Ry. in 1901. They were 8½ ft. long, 5 ins. and 8¾ ins. wide on top and bottom, and 3½ ins. deep inside. The weight was 205 lbs., which was too heavy for

practical use. At the middle (or at each end) was a transverse diaphragm to anchor the tie in the slag ballast, but these caused trouble in lining the track after it was surfaced. There were rectangular holes for T-head bolts, and the outer ends of the rail clips fitted into the holes. The track was ballasted with slag, and surfaced with limestone screenings blown under the ties by a Patterson air-jet machine. One piece of track after being surfaced and lined was left for two years without attention, but remained in good condition in spite of heavy traffic. It was proved that such ties could be properly tamped with picks, and that the rigid and secure rail fastenings resulted in less wear of rails on curves. This latter feature has also been observed with both steel ties and concrete ties on the Lake Shore & Michigan Southern Ry. The trough ties were still in use in 1907, but were less satisfactory than the I-beam ties already mentioned. The McCune steel tie, tried on the Monongahela Connecting Ry., is a rectangular inverted channel 8 ins. wide, 3½ ins. deep, with the ends raised ½-in. to form shoulders for the rails. It is pressed to shape cold from a 5/16-in. plate and weighs 160 lbs. The first ties were of 3/16-in. steel and 4 ins. wide, weighing 97 lbs., but such light and thin ties were not stable or durable enough for heavy main-track service.

Extensive trials with steel ties were at one time made on the New York Central Ry. In 1889, about 800 Hartford ties were laid; these were successful, and the cost of maintenance was low. A few years later a number of pressed steel ties were made (Fig. 26), having a bolted clamp fastening devised by Mr. Katte,

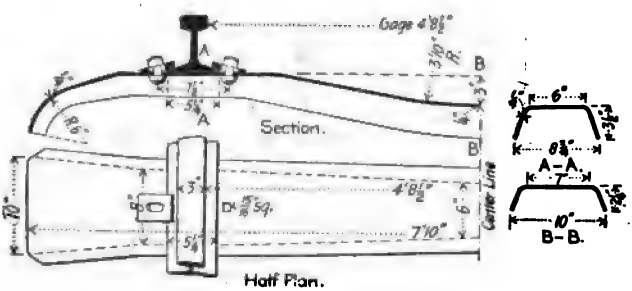


Fig. 26.—Steel Tie of New York Central Ry.

then Chief Engineer. They weighed only 86 lbs. (100 lbs. with fastenings), which was too light for the heavy traffic. They were durable, but required nearly twice as much work to keep them in surface as was required for the adjacent track with wooden ties. They were hard to line, the ballast shook away from them, and they made a noisy track. The quality of the steel, already referred to, was probably not suitable for the purpose. The Standard tie, tried on four or five railways, but now obsolete, was of channel section, placed with the open side up. Wooden blocks (with grain vertical) supported the rails, which were secured by clamps held by horizontal bolts through the blocks. The tie was filled with ballast, and the bottom was bent up at the middle to offer resistance to lateral motion, the ends being open. The weight was about 90 lbs. The Chester tie, tried on the Huntington & Broad Top Mountain Ry., had two inverted-trough rail-bearers, 12 ins. long, with stamped lugs to hold the inside of the rail base, the troughs being set parallel with the rails. They were connected by an inverted tee-bar passing through the sides of the troughs and having the top of

its web notched to hold the outer edge of the rail base. This did not admit of a change in gage or width of rail base, and when new rails were laid the ties had to be removed. The troughs weighed 25 lbs. each, and the tie-bar 20 lbs., or 70 lbs. for the tie complete.

Foreign Steel Ties.—The tie invented by Mr. Post, Division Engineer of the Netherlands State Railways, is used in many countries for lines of broad and narrow gage carrying light and heavy traffic. Fig. 27 shows the standard gage tie, its length being from 8 ft. 4 ins. to 8 ft. 10 ins. and the weight from 120 to 163 lbs. It is of varying section, being thinner, narrower and deeper at the middle than at the ends, thus combining strength and stiffness with an economical distribution of metal. The thickness is from 0.48 to 0.52-in. at the rail seats, decreasing to 0.24-in. at the middle, while the sides are from 0.24 to 0.36-in. thick. At the middle the tie is 4½ ins. deep and 5½ ins. wide over the bottom, with sides sloping 1 to 3. At the rail seats it is flat for 4½ ins. on top, 10¾ ins. wide over the bottom, and 2 ins. deep. The bolt holes are 1×1¼ ins., oblong, with rounded corners to prevent cracks. The bolts are ⅞-in. diameter, with T heads passing into the tie and held between ribs under the rail seat. An eccentric washer on the bolt allows for an adjustment of gage, and this is

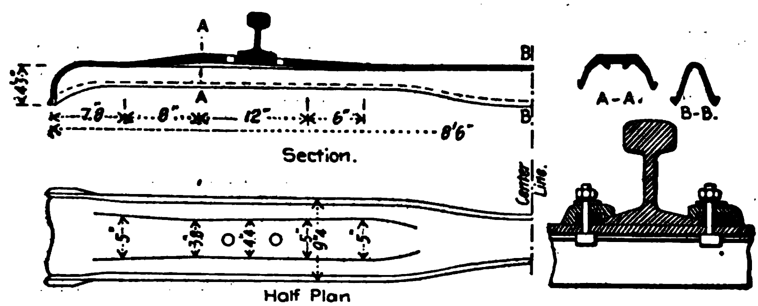


Fig. 27.—Post's Steel Tie.

secured by the clamp which holds the rail base. Tie-plates are sometimes placed under the rails. The joint or shoulder ties are 2 ft. apart, and the intermediate ties 3 ft. apart. The Post steel ties on the Gothard Ry., Switzerland, are 8 ft. 10 ins. long, 15/32-in. thick (at rail seat), and weigh 163 lbs. Allowing for the value of old material, these ties were actually cheaper in first cost than oak ties costing $1.20, and in tunnels the life is about the same, or from 8 to 10 years. Even if they were less economical than wood, the steel ties would still be used on account of the greater security of the track on the heavy grades and sharp curves on this mountain road, with its heavy engines and traffic. (Engineering News, April 7 and Aug. 25, 1898.) The latest ties of the German railways are of the Haarmann pattern; these are of trough section, 5 ins. wide on top, 10½ ins. over the bottom flanges, and 3 ins. deep; the metal is 0.35-in. thick in the top. On each side of the top is a rib, and between these lie the steel tie-plates. The outer end of the tie-plate has a hooked lug on the bottom which passes through a hole in the tie, while on the upper surface is a hooked lug to hold the rail base. Only one bolt is required to each rail, and this is on the inside. The ties are nearly 9 ft. long, and weigh 195 lbs. each. They are spaced 30 ins. c. to c., or 12 ins. at rail joints.

The Rendel steel tie, Fig. 28, is extensively used in India, South America and Mexico for lines of 5 ft. 6 ins., 4 ft. 8½ ins. and 3 ft. 3⅜ ins. gage. For the widest gage it is 9 ft. long, 4½ ins. wide on top, 8½ to 13 ins. wide on the bottom and 4½ to 5 ins. deep. The thickness is 13/32-in. on top and ¼-in. on the sides. Two lugs are stamped up at each rail seat, and a flat taper key is driven between the rail base and each of the lugs. The tie weighs about 135 lbs., and the keys 1 lb. each. The ties are usually laid about 3 ft. c. to c. Ties of this type on the Mexican Southern Ry. after 12 years' service appeared to be good for 12 years

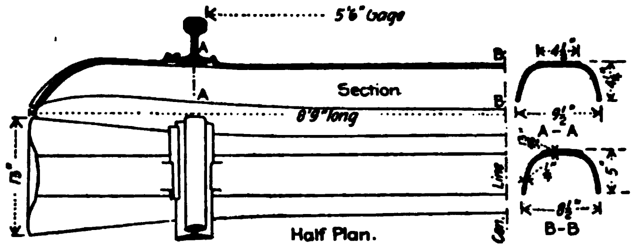


Fig. 28.—Rendel's Steel Tie; Indian State Railways.

more. The engineer proposed, however, to use a U-bolt fastening in place of the lug and keys, the horizontal leg of the bolt lying inside the tie. Most of the steel ties used in Europe are of inverted trough section.

Concrete Ties.

The extensive and varied applications of concrete within recent years have led to numerous experiments with concrete ties, but with poor results as a rule. If successful, they would have the advantage of enabling railways to make their own ties. They are of varying designs and with varied systems of steel reinforcement: old rails, rods, wire netting, boiler tubes, etc. In general the concrete is cut by the rails, if laid directly upon it, and it also disintegrates and cracks. About 5,000 of the Buhrer ties have been used. These are of practically rectangular section, but wider at the base, and the reinforcement is a piece of old rail placed inverted in the top of the tie, so that the track rails rest upon it. Bolted clamps fasten the track to the reinforcing rail, pockets in the concrete affording space for the bolt-heads. The tie is 6½ ins. deep, 4 ins. wide at the middle, and for about 4 ft. at each end it is 4½ ins. wide on top and 9 ins. at the bottom. With an 8-ft. piece of 65-lb. rail the weight is about 400 lbs. (230 lbs. concrete and 170 lbs. steel). The concrete is of 1 cement to 4 gravel; or 1 cement, 1 fine washed limestone, and 3 of ½-in. stone. On the Lake Shore & Michigan Southern Ry. they have been considered (after considerable experience) as making too rigid a track for high-speed trains (especially when the ground is frozen), being liable to cause breakage of rails. On the other hand, they are considered specially adaptable for sidetracks and yards, where they would be practically permanent and reduce the cost of maintenance.

Many concrete ties have wooden cushion blocks for the rails. The Percival tie is of inverted triangular section, reinforced by one rod in the bottom and three in the top, with wire stirrups at intervals. Blocks of hard wood are set in recesses in the face, and the screw spikes enter holes in the ties which are filled with babbitt metal or have threaded sleeves. The Campbell concrete tie,

used on the Elgin, Joliet & Eastern Ry., is of rectangular section, 6×7 ins., with beveled corners. At the rail seat, the width is increased to 10 ins., and the top corners are not beveled. The concrete is a 1:2:3 mixture, using crushed stone or slag or screened gravel; the reinforcement consists of two old boiler tubes, outside of which is an oval wrapping of wire netting. The weight is 356 lbs., including 35 lbs. of reinforcement. A steel tie-plate is embedded at each rail seat, and has holes at diagonally opposite corners for the legs of a U-bolt. Cast-iron rail clamps are fitted on the threaded ends. The Kimball tie, Fig. 29, tried on the Chicago & Alton Ry., has two concrete blocks 7×9×36 ins., 2 ft. apart, connected by a pair of 3-in. steel channels 8 ft. long and 2 ins. apart. Between the channels are spacing pieces into which are screwed bolts holding hard-wood blocks 3×9×18 ins. Each block has two ⅞-in. holes for the spikes, and elm plugs embedded in the concrete receive the points of the spikes. The

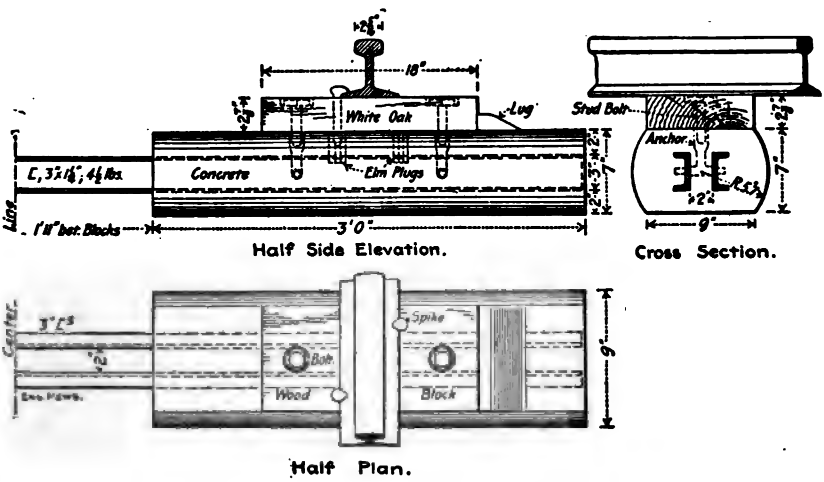


Fig. 29.—Kimball's Concrete Tie.

concrete is composed of 1 part of cement, ½ sand, and 2 of 1½-in. stone; or 1 cement to 2½ gravel. The weight is 436 lbs.: concrete, 374 lbs.; metal, 52 lbs.; wood, 10 lbs.

Relative Economy of Wood, Steel and Concrete Ties.

The results of an investigation made by Mr. W. C. Cushing, Pennsylvania Lines, as to the relative cost and economy of various kinds of ties are condensed and tabulated in Table No. 3. The first series of columns (A) show, for instance, that with white-oak ties costing 70 cts. and giving a life of 10 years, only 20 cts. can be paid for a tie of inferior wood treated with the zinc-tannin process and lasting 14 years; only $1.48 can be paid for a steel tie lasting 20 years. The second series of these columns (B) shows the price which a white-oak tie (10 years' life) must reach before it will be economical to use any of the others. Thus with oak at 70 cts., it is economical to buy inferior woods at 46 cts. and treat them by the zinc-chloride or the zinc-tannin process; at 86 cts. for oak, the same inferior ties may be treated by more expensive processes, or a

steel tie may be used at $1.75, lasting 20 years. Column C shows the life which ties of the prices given in columns 6 and 7 must have to be equivalent in economy to oak ties at 70 cts., 10 years. Thus a steel tie costing $1.75 must last $28\frac{1}{2}$ years. A uniform spacing of 1.833 ft. c. to c. is assumed, with prices as follows for the items included in "cost of tie in track": Laying, 12 cts. for wooden, 15 cts. for steel and concrete ties; spikes, 6.4 cts.; screw spikes, 15 cts. (3 cts. extra for helical steel linings); bolts, 10 cts. in steel ties, 16 cts. in concrete. Tie-plate, 32 cts. Application of fastenings, 3 cts. for spikes, 12 cts. for screw spikes, 7 cts. for bolts.

TABLE NO. 3.—COMPARATIVE ECONOMICS OF TIES.

A. Life and cost of tie equivalent to white oak at 70 cts., 10 years' life.
B. Cost of white-oak tie at which it will be economical to use others; life as in Col. 3.
C. Life of ties equivalent to white oak at 70 cts., 10 years; cost as in Cols. 7, 8.

		A			B			C	
1	2	3	4	5	6	7	8	9	10
Ties.	Fastenings.	Necessary life.	Cost* del.	Cost in track.†	W. oak del.*	Others* del. (Col. 1).†	Others in track (Col. 1).†	Life.	Cost of treating.
		years.	$	$	$	$	$	yrs.	cts.
White oak, untreated	Spike	10	0.70	0.91	....	....	....	10	..
Inferior woods:									
No tie-plates; zinc chloride.	"	10	0.48	0.91	0.68	0.46	0.89	$9\frac{3}{4}$	15
No tie-plates; zinc tannin	"	10	0.45	0.91	0.71	0.46	0.92	$10\frac{3}{8}$	18
Tie-plates; zinc chloride	Screw	12	0.10	1.06	1.01	0.46	1.42	18	15
Tie-plates; zinc tannin	"	14	0.20	1.19	0.90	0.46	1.45	$18\frac{1}{2}$	18
Tie-plates; zinc creosote	"	16	0.23	1.31	0.86	0.46	1.54	$20\frac{1}{4}$	27
Tie-pl.; creosoted, 30 cts	"	16	0.20	1.31	0.87	0.46	1.57	21	30
Tie-pl.; creosoted, 85 cts.	"	30	0.29	1.95	0.78	0.46	2.12	36	85
Steel	Bolt	20	1.48	1.86	0.86	1.75	2.13	$28\frac{1}{2}$	..
"	"	30	1.79	2.17	1.03	2.50	2.88	over 50	..
Concrete	"	20	1.15	1.53	0.91	1.50	1.88	$28\frac{1}{3}$	..
"	"	30	1.57	1.95	1.02	2.25	2.63	over 50	..

* Cost delivered; without treatment, fastenings or tie-plates.
† Cost in track includes freight, handling, laying, treatment, tie-plates, and rail fastenings.

CHAPTER 5.—RAILS

The T-rail or flange rail, which is now in common use all over the world, was invented in this country in 1830 by Robert L. Stevens, Chief Engineer of the Camden & Amboy Ry., and the first order was placed in England by him for this road. He also designed the hook-headed spike and flat splice bar, which have developed into the modern spike, fish plate and angle bar. The first rails weighed 36 and 40 lbs. per yd., and were in 16-ft. lengths. This rail was re-invented in England in 1836 by Charles B. Vignoles. The fish-plate joint was also re-invented in England by W. Bridges Adams, in 1847. A modification of the English bar rail was patented in England by Birkinshaw in 1820; this had a thin web with enlarged top and bottom ribs or flanges, being the forerunner of the English double-head and bull-head rails. It was not self-supporting, however, and had to be carried in cast-iron chairs. Thus it was entirely different from the Stevens design, which eliminated this complication by an entirely different section in the flat-bottom flange or tee-rail, which is self-supporting. The bridge rail, shown in Fig. 16, was designed in this country by Strickland in 1834, and in England by Brunel in 1835. It is rarely used.

When railway development was recommenced in 1865, after the close of the Civil War, attention began to be paid to the design of rails, and in 1865 Ashbel Welch designed a T-rail whose proportions approximated to those of modern sections, but whose head was rounded in accordance with the English practice of that day. About 1874, R. H. Sayre designed a rail having a head with top corners of large radius and sides sloping outward from the top, with the idea of reducing the wear caused by the wheel flanges. The Sayre 76-lb. rail adopted on the Lehigh Valley Ry. in 1883 had a flare of 10°, but in the 80-lb. rail, adopted in 1891, the flare was reduced to 5°, which was retained in the 90-lb. rail of 1895 (Fig. 30). The present standard of this road, however, is the Am. Soc. C. E. 90-lb. rail with vertical sides to the head. The Milholland section, proposed for the George's Valley & Cumberland Ry., carried the Sayre design to extremes, having a flare of 20°. It was based on the form of wear on sharp and frequent curves, but no such rails were made. The typical Sayre section is now obsolete, and it is generally recognized that the best results are obtained with sharp top corners and vertical sides to the heads, as noted further on. Some designers still adhere to a slight flare of 4° to 5°, with the idea of keeping the wheel flanges away from the corner of the rail head. The Providence & Worcester Ry. rail of 1885 had the sides sloped inward from the top, a design which is decidedly bad. Between 1880 and 1888 there was a tendency to give the rail head a large top corner radius of $\frac{3}{4}$ to $\frac{7}{8}$-in., to fit the fillet of the wheel tire. This, however, caused a considerable rubbing friction of the wheel flange on the rail head (aggravated in some cases by outward flaring sides to the head), in addition to the normal rolling contact with the wheel tread.

In 1873, the American Society of Civil Engineers appointed a committee to report upon the form, size, manufacture, test, endurance and breakage of rails, and also upon the comparative economy of iron and steel rails. In 1885, another committee was appointed to consider the proper relations of railway wheels and rails. It was asserted on the one hand that the rail head should have a round top corner and a head flaring outward from the top, to conform to the outline of the wheel fillet and flange. On the other hand, it was claimed that such a long line of contact would be dangerous (tending to cause derailment with sharp flanged wheels) and would cause undue wear and friction, and that therefore the rail head should have a sharp top corner and vertical sides in order to keep the wheel flange away from the rail head as long as possible. This committee's investigation showed the following: (1) The number and disadvantages of sharp-flanged worn wheels had been greatly exaggerated; (2) Sharp corners did not produce this character of wheel wear to the extent claimed; (3) Round-cornered rails showed greater side wear due to cutting by the wheel flange, while the rail wear became more rapid as soon as the side of the head began to be attacked; and (4) Rails often fail with little material abraded from the top by wear proper, being crushed after the flow of metal has reached its limit, and thus failing by rapid disintegration due to heavy wheel loads. In 1889 the committee recommended a broad head relatively to depth, with a top radius of 12 ins., $\frac{1}{4}$-in. top corners, 1/16-in. bottom corners, and vertical sides starting from a sufficient base width to give ample bearing for the joint.

This led to the appointment of a third committee to prepare designs for standard rail sections. At that time there was an almost entire lack of uniformity in rail design, each engineer having his own ideas, and desiring to have his own special form of section on his own line. The rail mills therefore had to carry

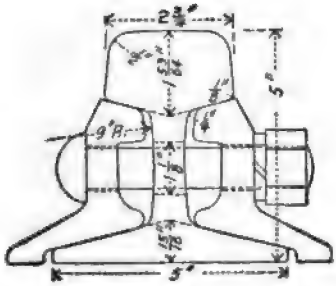
enormous stocks of rolls for all these sections, though many of the sections were practically identical, having minute variations as the result of the whim of the designer or his ignorance of the existence of a practically identical section. This committee made a very thorough investigation, and in 1893 presented its report (which was adopted), recommending standard sections, in which the metal was distributed as follows: Head, 42%; web, 21%; base, 37%. This is a good distribution for rails of good material, and thoroughly rolled. This type of section is shown in Fig. 31. The sections vary by 5 lbs. from 40 to 120 lbs. per yd., and in all of them the height and width of base are equal, while the following dimensions are constant:

	Radius.		Radius.
Top of head	12 ins.	Side of web	12 ins.
Top corners of head	$\frac{5}{16}$ in.	Top fillets of web	$\frac{1}{4}$ in.
Bottom corners of head	$\frac{1}{16}$ in.	Bottom fillets of web	$\frac{1}{4}$ in.
Corners of base	$\frac{1}{16}$ in.	Fishing angles	13°

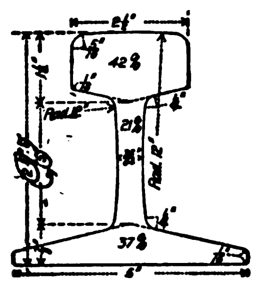
These sections have been very extensively adopted, with advantage to rail makers as well as users, as their adoption enabled the mills to roll rails for stock. The rails can be rolled at a lower temperature and require less cambering than sections having a greater proportion of the metal in the heads. There are also fewer "wasters" or "seconds" from rails rolled to these sections, and the sharp corners have no material effect upon the life of the rolls. It will be noticed that the third committee adopted $\frac{5}{16}$-in. as the radius of the top corner, instead of $\frac{1}{4}$-in., as recommended by the second committee. This was partly to effect a compromise with the advocates of a round corner, and partly to make the section more generally applicable on curves. The section was designed particularly for the tangents and easy curves which compose by far the greater part of the railway system. It is, however, largely and successfully used on lines having a large percentage of very sharp curves, and special sections are rarely desirable. An investigation made by the author in 1900 showed that out of 50 leading railways (120,000 miles of road), 35 railways (with 75% of this mileage) had adopted this form of section as standard. It also showed that no excessive wheel wear had been caused by the sharp-cornered rails.

Modifications of the Am. Soc. C. E. sections for the heavier weights have been proposed at different times; in 1902 another committee was appointed to report upon this matter, and upon the chemical composition and the methods of manufacture. The report presented in 1906 showed the great extent to which these sections had been adopted, representing from 65 to 99% of the output of leading mills. It pointed out also that since the adoption of these sections in 1893, wheel loads and train speeds had been greatly increased; driving-wheel loads had increased 60%, while the maximum weight of rails had increased only 25%. It should be noted also that in many cases the increased wheel loads were not accompanied by any increase in weight of rails. The committee, however, did not then feel justified in recommending any change of section, but showed that unsatisfactory service of the heavy rails was largely accounted for by the changes in methods of manufacture. The principal of these were in the rolling of rails with too rapid a reduction and at too high a temperature. One proposed modification was to increase the depth of the rail head to enable it to resist bending or crushing down under heavy loads; on the other hand, it was proposed to increase the proportion of metal in the web and base in order to equalize the cooling during mill operations. In 1907, however, the

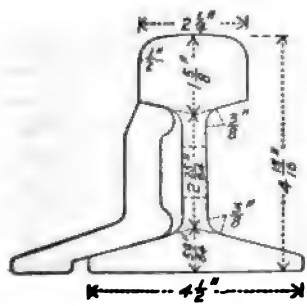
committee decided to prepare modified designs for the heavier sections. The Am. Soc. C. E. type of section is undoubtedly in general satisfactory, and it is to the manufacture we must look for improvement in quality. A committee of the American Railway Association in 1907 reported that there was no necessity for a radical change in this type of section so far as its relation to the wheel is concerned, but that criticisms are based on an effort to strengthen the rail by a better disposition of the material, or an effort to so modify the section as to obtain better results in manufacture. The relation of wheels to rails and frogs is discussed in Chapter 7.



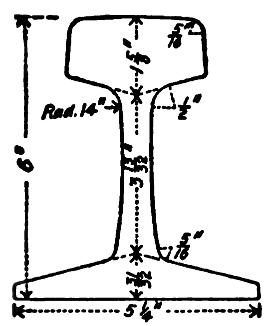
90 lbs.
Fig. 30.—Sayre Type.



80 lbs.
Fig. 31.—Type of American Society of Civil Engineers.



72 lbs.
Fig. 35.—Sandberg Rail Section.



100 lbs.
Fig. 32.—Dudley Type.

As to the form of section, then, it may be said that the consensus of experience and investigation is that the head should be broad and relatively thin, with sharp top corners of $\frac{1}{4}$-in. (or $\frac{5}{16}$-in.), sides vertical (or nearly so), and having fishing angles of not less than 13°. The flatter the under side of the head can be made, without affecting the rolling, the better; and the top and bottom fishing angles should be the same. In England, the standard is 14° for tee and 20° for bullhead rails. The web may be made with either vertical or curved sides. The latter design gives no greater strength, but is claimed to give a better compression of the metal in the thick parts at the union of the web with the head and base. In the Am. Soc. C. E. sections the minimum thickness is at the middle of the rail, but in the Dudley sections (noted below) it is nearer the

head. Flat-topped rail heads have been advocated, but early experiments showed that the metal in the head would not get so much work or compression from the rolls, and would thus be of less dense texture on the wearing surface than is desirable. In addition to this, the lateral play of the wheels would soon wear the top to a curved outline. The usual top radius is 12 or 14 ins. A 20-in. radius has been used, and the Chicago, Milwaukee & St. Paul Ry. made it 18 ins. for its 75-lb. rails, but has adopted the Am. Soc. C. E. section with 12 ins. radius. Any less radius is objectionable, but the Pennsylvania Ry. has adopted 10 ins. and the Sandberg sections have 6 ins.

The width of base should be equal to, but not greater than, the height of the rail; if metal tie-plates are to be used, the width of base may be less than the height. The edges should not be too thin, and should be vertical, with 1/16-in. top and bottom curves, the latter reducing the cutting of the ties by the sharp edges. Increasing the width of base has little effect in reducing the cutting of ties, which is due to the motion more than to the direct pressure of the rail, while the metal in the extra width of base between the ties is practically useless. In order to roll the very wide thin flanges while hot the rails have to make the finishing passes with the metal in the head too hot to be properly compacted and hardened in rolling. Mr. Sandberg some years ago increased the width of rail base in his sections so as to avoid the use of tie-plates, for while he advocated their use, he found it difficult to get them introduced by the European railways which largely use his sections. The rail section as a whole suffered in consequence. In 1905, the Atchison, Topeka & Santa Fé Ry. made a trial of a 101-lb. rail designed to give a larger bearing on the ties and to be used without tie-plates. It was 5¾ ins. high and 6¾ ins. wide (even wider than the Sandberg rail above noted); the head was that of the 85-lb. Am. Soc. C. E. section. The mills had great trouble in rolling the rails, and when laid they broke very readily in the base. The effect upon the ties was said to be satisfactory, but under heavy traffic and wheel loads the ties (especially if of soft wood) would almost certainly continue to be cut by the rail. It is generally recognized as better to protect the ties by metal or wooden tie-plates. The Italian approach of the Simplon tunnel is laid with a tee-rail having a base much narrower than the height but of more than usual thickness, so that it is a favorable section for rolling. This is laid on heavy cast-iron tie-plates and secured with screw spikes.

The rapid increase in weight of locomotives, cars and train loads has led to the use of heavier and stiffer rails in the sense of girders to carry the increased loads; and correspondingly wider heads are required to sustain the increased wheel pressure ratios per square inch of surface contact between rails and wheels. Where this was not done, the metal of both rails and tires has been in some cases overtaxed, excessive wear and flow taking place, and neither wheels nor rails giving as good service as had been expected. Broad, well-worked heads are required for the best efficiency of both rails and wheels. With this in view and as the result of the inspection of some 25,000 miles of track with his dynagraph car, Mr. P. H. Dudley designed a set of rail sections to meet the conditions of service thus ascertained. This type is shown by the 100-lb. rail of the New York Central Ry., in Fig. 32. It will be noticed that the fillets are of large radius, and that the narrowest part of the web is above the center line. This was designed to give extra resistance to twisting, so that the head will not bend over the web, nor the web over the base. The first of these was designed in 1883 for the New York Central Ry. The relation of good heavy rails to economy in operation is shown

by experiments in which hauling a train load of 378 tons at a speed of 55 miles per hour required 820 HP. on 65-lb. rails, and 720 HP. on 80-lb. rails, while it was estimated that only 620 HP. would have been required on 105-lb. rails. Broad-top rails replacing narrower rails may show apparently excessive wear at first, owing to the wheels having been worn to the narrower head, and this insufficient bearing may also cause the wheels to slip. The train resistance of freight trains of 25 to 30 cars (600 to 700 tons) on light rails at 18 miles per hour was 6 to 8 lbs. per ton; while with trains of 80 cars (3,428 tons) on Dudley 80-lb. 5¼-in. rails at 20 miles per hour, it was only 3 lbs. per ton. These stiff heavy rails also reduce the work of maintenance and renewals from 20 to 50% and are especially valuable where maintenance work is heavy, as on steep grades, in tunnels, etc. The following is from a statement by Mr. Dudley:

"The static pressures under passenger-car wheels on rail heads 2¼ to 2¾ ins. wide, range from 30,000 to 100,000 lbs. per sq. in., while those of locomotive driving wheels range from 110,000 to 150,000 lbs. To sustain such wheel pressures without undue flow and wear requires not only broad heads, but a high grade of metal in the rails. Comparisons of tire records on the New York Central Ry. before and after the use of the Dudley 80-lb. rail (5¼ ins. high, 5 ins. width of base, 2 21/32 ins. width of head and 5/16 in. corners of head) show that with an increase of 40% in weight per driving wheel the mileage per 1/16-in. of wear per tire is about the same for the heavier locomotives on the 80-lb. rails, as formerly for the lighter locomotives on the 65-lb. rails. The former carried 20,000 to 23,000 lbs. per wheel, and averaged 19,300 miles per 1/16-in. wear of tire. The latter carried 13,360 lbs. per wheel, and averaged 19,400 miles per 1/16-in. wear. Since the general use of this 80-lb. rail, the locomotives rarely go to the shop to have the driving-wheel tires turned unless other repairs are needed, the wear of the tires no longer determining when the engines must go to the shop, as was the case when running on the 65-lb. rails. The mileage before re-turning the tires is from 150,000 to 190,000 miles. These facts show the value of the broad heads in increasing the life of tires as well as of rails."

A new rail section of notable design was introduced in 1907 by Mr. R. W. Hunt, the expert in steel manufacture and rails. Its special features are the distribution of metal and the form of the base, giving a good section for rolling, and causing the head and base to cool at about the same rate, thus avoiding cooling stresses. The base is thick and narrow, and in this respect the section resembles the Italian rail above noted. Less favorable features are the narrow head, and round top corners. The dimensions of the 100-lb. rail (Fig. 33) are given in the accompanying table; it has a cross-sectional area of 9.87 sq. ins. (head, 3.56; web, 2.27; base, 4.04). This rail was designed with a special view to re-rolling when worn; giving an 80-lb. rail after two such treatments. Another peculiar rail is that of the Great Northern Ry. (Fig. 34), having flaring sides and a ⅝-in. corner radius, which is the largest radius now in use. A somewhat similar section is standard on the Gould railway system. The Chicago, Burlington & Quincy Ry. has an 85-lb. rail conforming very closely to the Am. Soc. C. E. section, but modified unfavorably with a 5° slope and ⅜-in. corner radius for the head. The tee-rail sections adopted by the British Engineering Standards Committee in 1905 are similar to the American sections in that the height and base width are equal and that the head has vertical sides and a top radius of 12 ins. They differ from them as follows: (1) The distribution of metal is not uniform for all weights; (2) the top corner radius is larger, and is not uniform; (3) the fishing angle is 14°; (4) the upper surface of the base has not a uniform slope, being 1 in 10 beyond the splice-bar seat; (5) the sides of the web are vertical.

The form of the base is such as to give less depth in the center, and consequently a slightly smaller percentage of the metal than in the American sections, but it also gives a somewhat greater thickness in the outer part of the base. In the section designed by Mr. Sandberg, the European rail expert, and used somewhat extensively, the heads are wide, with corners of large radius, as shown in the accompanying table. He claimed that the wide radius was necessary for the long rigid wheel base of European cars, but this has been disputed, and in any case the cars are now largely mounted on trucks. The dimensions and proportions of a number of modern rail sections are given in Table No. 4.

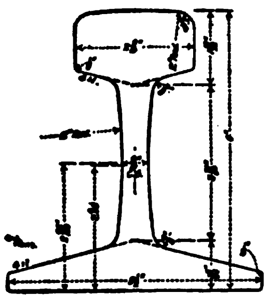


Fig. 33.—Hunt Rail Section.

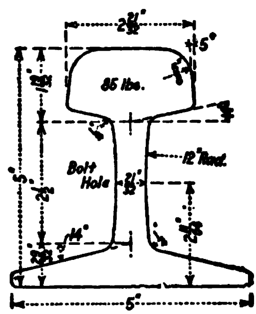


Fig. 34.—Rail Section of Great Northern Ry.

The advantages of heavy rails for tracks carrying heavy loads and heavy traffic, and the increased efficiency and economy due to the use of such rails, are now widely recognized, as shown by the very extensive adoption of heavier rails which has been noticeable for the past few years. The increase in weight, however, has been by no means proportionate to the very striking increase in traffic and in wheel loads. Besides properly sustaining the traffic, the rails must be heavy enough to have a margin of safety to provide against the exigencies of badly tamped or widely spaced ties, the heaving of the roadbed in winter, and the effects of flat or eccentric wheels. Stiffness is as important as weight in rails under heavy and fast trains, and this is one of the principal reasons for an increase in weight. It is also one reason why a reduction in weight of rail cannot properly be made for a closer spacing of ties or even with a continuous bearing for the rails. As the weight is increased the fiber stresses in the rail decrease, as shown later on. Increase in weight of rails should be accompanied by a corresponding increase in strength or stability of the substructure which carries them.

Mere increase in weight does not necessarily insure improved service, but design and manufacture are of great importance (especially the latter). In a rail having a large proportion of metal in the head, the metal will not be thoroughly rolled, and this coarse-grained or soft metal is more rapidly worn. As only a certain depth of surface wear can be allowed before the rail becomes unserviceable, the large head may really give no more wear than a lighter rail with a head so proportioned as to be rolled hard and dense. A good heavy rail, however, is a profitable investment, not only in point of service, but also in giving a stiffer and easier riding track. The heavier and stiffer rails give a better dis-

TABLE NO. 4.—DIMENSIONS OF RAIL SECTIONS.

	Railway and Type of Section.															
	A. S. C. E.	N. Y. C. Ry. Dudley.	Penna. Ry. P. Ry.	R. W. Hunt.	Sandberg.	British Standard.	L. V. Ry. Sayre.	Ph.&Read.Ry. A. S. C. E.	G. N. Ry.	Wes. Pac. Ry. Gould Std.	C. B. & Q. Ry.	Mich. C. Ry. A. S. C. E.	N. Y. C. Ry. Dudley.	N. Y. C. Ry. Dudley.	Penna. Ry. P. Ry.	A. S. C. E.
1. Weight per yard ....lbs.	100	100	100	100	100	100	90	90	85	85	85	80	80	75	70	60
2. Height ....ins.	5 3/4	6	5 1/2	6	5 3/4	5 3/4	5	5 3/8	5	5 1/4	5 3/16	5	5 1/8	5	4 1/2	4 1/4
3. Width of base ....ins.	5 3/4	5 1/2	5 1/2	5 1/2	6 1/4	5 3/4	5	5 3/8	5	5 1/4	5 3/16	5	5	4 3/4	4 1/2	4 1/4
4. " " head, top ......ins.	2 3/4	.....	.....	2 9/16	3	2 3/4	.....	2 5/8	.....	.....	.....	2 1/2	.....	.....	.....	2 3/8
5. " " " bottom...ins.	2 3/4	3	2 13/16	2 9/16	3	2 3/4	2 3/4	2 5/8	2 21/32	2 1/2	2 21/32	2 1/2	2 21/32	2 5/8	2 7/16	2 3/8
6. Side of head, slope.......deg.	Vert.	4	4	Vert.	Vert.	Vert.	5	Vert.	5	4	5	Vert.	4	4	4	Vert.
7. Depth of head ....ins.	1 45/64	1 5/8	1 7/8	1 19/32	1 7/8	1 53/64	1 53/64	1 19/32	1 19/32	1 3/4	1 25/64	1 1/2	1 1/2	1 3/8	1 13/32	1 7/32
8. Height of web ....ins.	3 5/64	3 13/32	2 11/16	3 31/64	.....	3	2 15/64	2 51/64	2 1/8	2 5/8	2 3/4	2 5/8	2 3/4	2 3/4	2 1/8	2 17/64
9. Depth of base ....ins.	31/32	31/32	15/16	1 5/64	.....	57/64	13/16	59/64	29/32	7/8	57/64	7/8	7/8	7/8	25/32	49/64
10. Thickness, web ....ins.	9/16	19/32	5/8	9/16	17/32	41/64	5/8	9/16	21/32	9/16	9/16	35/64	17/32	17/32	1/2	31/64
11. " edge ....ins.	.....	9/32	11/64	.....	3/8	.....	1/8	.....	.....	.....	.....	.....	1/4	.....	9/64	1/4
12. Height to center of hole....ins.	.....	2 5/8	2 9/32	2 25/128	.....	.....	2 1/16	.....	2 11/64	2 3/16	2 9/64	.....	2 1/4	2 1/8	1 27/32	.....
13. Radius, top of head ......ins.	12	14	10	12	5 3/4	12	12	12	12	10	12	12	14	14	10	12
14. " top corner of head.ins.	5/16	5/16	7/16	3/8	1/2	3/8	1/2	5/16	3/8	7/16	3/8	5/16	5/16	5/16	7/16	5/16
15. " bott. " " " .ins.	1/16	1/16	1/8	1/8	Sh'rp	1/16	1/8	1/16	1/8	1/8	1/8	1/16	1/16	1/16	1/8	1/16
16. " top fillets.........ins.	1/4	1/2	1/4	3/8	.....	1/4	1/4	1/4	1/4	5/16	1/4	1/4	1/2	1/2	1/4	1/4
17. " bottom fillets....ins.	1/4	5/16	1/4	3/8	.....	1/4	1/4	1/4	1/4	5/16	1/4	1/4	5/16	5/16	1/4	1/4
18. " corners of base...ins.	1/16	1/16	11/64 rd.	1/16	.....	1/16	1/16	1/16	3/32	1/16	1/16	1/16	1/16	1/16	9/64	1/16
19. " sides of web .....ins.	12	14	8	12	Vert.	Vert.	9	12	12	Vert.	12	12	14	14	8	12
20. Edge of base	Vert.	Vert.	Rd.	Vert.	Vert.	Vert.	Vert.	Vert.	Vert.	Vert.	Vert.	Vert.	Vert.	Vert.	Rd.	Vert.
21. Fishing angle, head ......deg.	13	14	13	14	20	14	14	13	14	13	13	13	14	14	13	13
22. " " base ......deg.	13	14	13	14	20	14	14	13	14	13	13	13	14	14	13	13
23. Metal in head.......per cent.	42	40.8	46	36.07	46	45.2	47.8	42	42	45.7	.....	42	42.2	41	48	42
24. " " web ....per cent.	21	23.5	20	23.00	17	18.4	18.2	21	22	18.0	.....	21	21.1	23	18	21
25. " " base ....per cent.	37	35.7	34	40.93	37	36.4	34.0	37	36	36.3	.....	37	36.7	36	34	37

tribution of the stresses within the rail itself, and a better distribution of the load upon the ties and the roadbed, with considerably less dynamic effect. Having less deflection, they do not creep so much; they do not deflect so much at the joints, and the receiving ends do not cut out so much; while the rails do not "roll" so much, even without tie-plates, so that there is less work in maintaining the gage. The great trouble of recent years has been that the heavy rails are of inferior quality, giving poor service and being specially troublesome on account of fracture. As steel is homogeneous, the failure of rails in service is not by splitting and lamination, as in iron rails, but by (1) normal wear or abrasion of the head, (2) cutting out and bending at the joints, due to the blows of the wheels, (3) the flow of the metal of the head under heavy wheel pressures, and (4) largely by fracture due to various conditions of improper composition, defective manufacture, excessive loading and low atmospheric temperatures.

Rails of 100 lbs. per yd. are in use on the busy divisions of several important lines, and also in such special locations as tunnels and terminal approaches. That of the New York Central Ry. (Fig. 32) was the first to be rolled in this country. It was first adopted for the four-track line approaching the New York terminal, in order to reduce the difficulty and expense of maintenance and renewals on tracks so crowded with traffic and laid largely in tunnel and in open cut with retaining walls. With light rails under considerable traffic, the diminished life of rails and ties, the increased cost of material and labor for maintenance and renewals, and the occasional sums involved in repairs and damage suits after wrecks, more than balance the cost of rails of suitable weight which will make a better track. For ordinary freight and passenger traffic on roads with easy curves and grades, the weight should be from 70 to 75 lbs. For extra heavy freight traffic or fast passenger traffic, or on lines with sharp curves and steep grades, the weight should be from 80 lbs. upwards, and rails of 80, 85, 90, 95 and 100 lbs. are in service on various roads. A 110-lb. rail 6¼ ins. high and wide was designed for the Chignecto Ship Ry. (Canada), but this line was never built. In calculating the weight of any section, the weight of steel is usually taken as 10.20 lbs. for a 36-in. bar of 1 sq. in. For rails of 95 lbs. and over, however, 10.18 lbs. is found to give a closer result. It may be pointed out that the rail is only one part of the track, and that improvements in ballast, ties, fastenings, joints, etc., are of equal importance in the construction and maintenance of a first-class track. At rail joints the corners (on new rails) may cut the wheels unless the rails are in perfect alinement. New rails laid on old ties may be given a wavy surface or a permanent set due to careless handling or to uneven bearing surfaces. This cannot afterwards be remedied, and will materially reduce the benefits that should result from the new rails. The laying of heavier rails on ordinarily good track should reduce the work of maintenance and renewals. It has already been explained that the number of ties should not be reduced when heavier rails are introduced.

The ordinary length of rails is 30 ft. (at 70° F.), but many railways have adopted 33 ft. as the standard length, thus reducing the number of joints by 10%. The Lehigh Valley Ry. has used 45-ft. rails, which are also employed in the Hoosac Tunnel (Boston & Maine Ry.). Rails 60 ft. long are used to some extent at tunnels, bridges, etc., as well as in ordinary track. There is sometimes difficulty in turning these long rails on the right of way, but the Norfolk & Western Ry. has 85-lb. 60-ft. rails which are not found particularly awkward to handle. The use of 60-ft. rails is limited, partly on account of the very

wide expansion opening at the joints. They are being used by a number of electric interurban railways, which find them more difficult to handle and to keep in line, but in some cases easier to keep in surface, than 30-ft. or 33-ft. rails. Continuous rails, with the ends welded together in the track, are extensively used on street railways, and have been tried experimentally (but with bolted or riveted joints) in railway track. With this arrangement no expansion spacing is given. In 1893, Mr. Torrey, Chief Engineer of the Michigan Central Ry., laid six consecutive stretches of continuous rails, 800 ft., 500 ft., 250 ft. and 100 ft. in length. The rails were laid end to end, and the rails and splice bars were then drilled for 1-in. turned bolts. Switch points were used to allow for expansion at the ends of the lengths. The 800-ft. length was afterwards reduced to 500 ft., on account of excessive expansion, but the track is said to have given very satisfactory service.

Steel rails were first rolled in England about 1855; and in the United States experimentally in 1865, and to order in 1867, when the improvement of the Bessemer process of 1862 (largely due to and introduced in this country by A. L. Holley) led to greatly increased facility of manufacture and a decrease in cost. This process (with Holley's improvements) and the consequent introduction of steel rails at moderate prices were great factors in the enormous railway development of this country, and iron rails are now obsolete. The acid Bessemer process, in its turn, is declining. It is not adapted to ores high in phosphorus and sulphur, of which immense quantities are available in this country, and little has been done in the introduction of the basic-Bessemer process. There is, however, a marked development in the use of the basic open-hearth process, which allows for the use of these high-phosphorus ores and the better control of the phosphorus. The most important metalloids in the metal are carbon, silicon, manganese, phosphorus and sulphur. The first three have a high affinity for oxygen, and are readily removed from the metal at high temperature by the oxygen of the air. The other two, being chemical acids (forming acid compounds when oxidized), must be exposed to the action of lime or other mineral bases having sufficiently active affinity for the phosphorus and sulphur to remove them from the iron. A silicious (or acid) lining in the Bessemer converter or open-hearth furnace will be fluxed and destroyed if these mineral bases are used, and can consequently be used only with metal sufficiently low in phosphorus and sulphur to yield a satisfactory product without this treatment. A basic lining (of magnesite or dolomite) allows of large additions of lime to the molten metal and also of oxides of iron (ore, mill scales, etc.).

In the Bessemer process, the metal from the blast furnaces is delivered by 15- or 20-ton ladles to a mixer or tank. From this the molten metal is taken by other ladles and charged into 10- or 15-ton converters, a certain proportion of scrap being then added. Air at about 25 lbs. pressure is blown in from the bottom of the converter and in a few minutes burns out the silicon and carbon. The proper degree of carbon and manganese are then added by a charge of spiegeleisen (in the converter or the casting ladle), and the steel is then poured into the casting ladle and thence into the ingot molds. The ingots are generally about 18×22 ins., 5 to 5½ ft. long, weighing from 5,000 to 6,000 lbs. When solid, the ingot is taken from the mold and set upright in a furnace called a soaking pit until needed. The ingot is first rolled in a blooming mill, which reduces it to a bloom or bar about 8 or 9 ins. square and 24 ft. or 15 ft. long. The bloom is then cropped at least 12 ins. at the ends, to cut off any spongy parts or piping,

and cut in two or three lengths according to the weight of rail to be made. The bloom may then be reheated or go direct to the rail mill. Here the roughing rolls and intermediate rolls (with five passes each) give it the approximate shape. The finishing rolls give it the required section and form the name of maker, date, weight of rail and other marks on the web of the rail. The hot rails are then cut by circular saws to such a length that they will be 30 ft. (or as required) when cold. They then go to a cambering machine, and then to the cooling beds, where the camber (6 to 12 ins. according to the distribution of metal in the section) is taken out in cooling. When cooled, the rails go to the cold-straightening press, where any kinks are taken out. The burr left by the saws is then chipped off and the ends are filed. The rails are then measured for length, drilled for the bolt holes, and placed on the inspection or shipping beds. (Blooming, 6 to 12 passes. Finishing, 1 to 5 passes. Shrinkage of rail, 6 to 7 ins.)

In the open-hearth process, the metal is taken from the mixer to the open-hearth furnace, where lime is added and also oxide in the form of ore and mill scale. The oxide eliminates the metalloids and the lime absorbs the phosphorus and sulphur. The process takes about two hours (instead of a few minutes), but the furnace handles a charge of about 50 tons (instead of 15 tons). The furnace is then tilted, and at once recharged. The metal from the furnace is poured by the casting ladle into ingots which are handled as above described. The process is expedited at some plants by a duplex process in which the metal is first treated in Bessemer converters for the removal of the carbon and silicon, and then delivered to the open-hearth furnaces.

The quality and wearing property of rails depends upon the chemical composition and the treatment in manufacture, but more especially upon the latter. The finer the grain the better the wearing quality, and this is produeed by mechanical treatment at low temperature. Rails should be rolled slowly for the finishing passes and at a comparatively low temperature (about 1600° F.) in order to produce a metal of close or fine-grained texture. The work done upon very hot rails has little effect in reducing the coarse texture. The higher the carbon, the more important is this finishing treatment. With the higher temperatures (2,000° or 2,200° instead of 1,600°), higher speed of the rolls (900 ft. per min. instead of 400 ft.), and fewer number of passes for the bloom (6 to 10 instead of 13 or 15), rails cannot be expected to be of as good quality as those made under the opposite conditions. Speed of output is the main aim, and as the men are paid by the ton, they also have an interest in a large and rapid output. As the mills are full of work there is no liability of any change in process that will reduce the capacity of output. In the Kennedy-Morrison system an attempt is made to effect a compromise by holding back the rails before sending them to the finishing rolls. As they come from the intermediate train they are run to a cooling bed and held from 45 to 90 seconds. This involves little actual delay, as when once the bed is filled there is the same rate of output from the finishing rolls. Each rail is laid with its head against the base of the previous one, so that the rails will cool equally, the more rapidly cooling flange of one absorbing heat from the hot mass of metal in the head of the next. The rails have a temperature of about 1,740° to 1,765° on reaching the bed, and from 1,575° to 1,600° on leaving the finishing rolls. They are said to have a closer grain, and to require less cambering, owing to the smaller difference in temperature of the head and base. It appears, however, that in practice the close grain is in the top of the head rather than in the entire body of the rail.

In order to obtain the desired low finishing temperature the specifications of the American Railway Engineering Association provide that the number of passes and speed of rolls must be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws of 6 ins. for 85-lb. and 6⅛ ins. for 100-lb. rails; no artificial means of cooling the rails to be used between the finishing pass and the hot saws. An alternative is to specify a temperature at the finishing rolls of not over 1,600° F. for rails rolled from reheated blooms, or 1,750° F. for rails rolled direct from the bloom. The specifications of the American Society of Civil Engineers are similar, but give a shrinkage allowance not exceeding 6 7/16 ins. for 33-ft. 100-lb. rails and 1/16-in. less for each 5-lb. reduction in weight, with a decrease in the allowance for delay between the final pass and the saws. The New York Central Ry. specifies 5⅜ and 6 ins. for 30-ft. and 33-ft. 80-lb. rails, and 5½ and 6⅛ ins. for 100-lb. rails. These important shrinkage requirements are largely ignored by the mills.

The maximum camber allowed at any point in a rail when it reaches the cold-straightening press is very generally 5 ins., but many engineers consider it desirable to limit this to 3 ins., especially as a 5-in. camber is unusual. The gag or ram of this press should not be applied to the head of the rail and must not leave marks on the rail. The supports should be 42 ins. apart for heavy rails; the New York Central Ry. requires 36 ins. for weights up to 70 lbs. per yd., 40 ins. to 80 lbs., and 44 ins. for 100 lbs. Some better system of straightening is much to be desired, as many rails are injured in this treatment and prove defective in the track.

One of the most important chemical constituents of rail steel is the carbon, the proportion of which ranges from 0.40 to 0.45% for 60-lb. rails, to 0.60 to 0.70% for 100-lb. rails. The maximum is 0.65 to 0.75% in 80-lb. rails for the Boston Elevated Ry.; this was adopted as the result of experience with some special rails having 0.78% carbon. The New York Central Ry. specifies 0.65 to 0.70% for 100-lb. rails, but any higher percentage is rejected. The object of the high carbon proportion is to make the steel hard, but it is liable to render it brittle unless special care is taken in proportioning the other chemical components and in the process of manufacture. With proper heat treatment and proper rolling, however, a high-carbon rail can be made combining hardness (to resist wear) with toughness (to resist fracture); such rails have given excellent results in service. The general experience in the United States is that well-made high-carbon rails give a longer life and are not more liable to fracture, while they are much less subject to flow or deformation under heavy loads. It was at one time suggested that low-carbon steel would give the best wearing qualities, but a very little experience exploded this fallacy.

Phosphorus is one of the most troublesome constituents, and Bessemer rails have usually too high a proportion of this in relation to the carbon. The usual specified limit is 0.085%, but in practice 0.1% is reached (and even exceeded) in high-carbon rails. This combination of high phosphorus with high carbon and hot rolling is apt to produce a brittle rail, but under the Bessemer process it is not easy to reduce it. This is one reason for the rapid modern development of the open-hearth process which gives a better control of the phosphorus. Sulphur is also objectionable, tending to cause seams. A small proportion of manganese gives a smooth surface and good rolling quality, but if high it may lead to fracture. Silicon tends to make the steel both tough and hard. Mr. Sandberg con-

siders that it should be eliminated in the converter (as an impurity) and then added as ferro-silicon to produce the required results.

The chemical proportions for rails cannot be stated arbitrarily or uniformly, but the specifications must be prepared with regard to the quality of the ore to be used and the weight of the rail. The design and the methods of manufacture are as important as the chemical proportions. Some roads do not specify the chemical composition, but the rails are subject to inspection (as to manufacture) and tests by the railways. Mr. R. W. Hunt thinks it best to specify only the carbon, silicon and phosphorus, leaving the rest to the judgment of the manufacturer, as quality must depend more upon the manufacture than upon the chemical composition. A number of specifications are given in Table No. 5, and it will be seen that in some of these there is no mention of the sulphur content.

TABLE NO. 5.—SPECIFICATIONS FOR CHEMICAL COMPOSITION OF RAILS.

Specifications.	Weight. lbs. per yd.	Percentage of— Carbon.	Phosphorus.*	Manganese.	Sulphur.*	Silicon.*
		A. Bessemer Steel.				
Am. Soc. C. Engrs.	70 to 79	0.50 to 0.60	0.085	0.75 to 1.00	0.075	0.20
and	80 " 89	0.53 " 0.63	0.085	0.80 " 1.05	0.075	0.20
Am. Ry. Eng. Assoc.	90 " 100	0.55 " 0.65	0.085	0.80 " 1.05	0.075	0.20
Mfrs. Association	70 " 80	0.40 " 0.50	0.10	0.75 " 1.05	....	0.20
and	80 " 90	0.43 " 0.53	0.10	0.80 " 1.10	....	0.20
Am. Soc. Test. Matls.	90 " 100	0.45 " 0.55	0.10	0.80 " 1.10	....	0.20
N. Y. Central Ry.† ...	65	0.45 " 0.55†	0.06	1.05 " 1.25	0.069	0.15 to 0.20
N. Y. Central Ry.. ...	70	0.47 " 0.57†	0.06	1.05 " 1.25	0.069	0.15 " 0.20
N. Y. Central Ry.. ...	80	0.55 " 0.60†	0.06	1.10 " 1.30	0.069	0.15 " 0.20
N. Y. Central Ry.. ...	100	0.65 " 0.70†	0.06	1.20 " 1.40	0.069	0.15 " 0.20
Mo. Pacific Ry.......	60 to 70	0.38 " 0.48	0.10	0.70 " 1.00	....	0.20
Mo. Pacific Ry.......	70 " 80	0.45 " 0.55	0.10	0.75 " 1.05	....	0.20
Mo. Pacific Ry.......	80 " 90	0.48 " 0.58	0.10	0.80 " 1.10	....	0.20
Mo. Pacific Ry.......	90 " 100	0.50 " 0.60	0.10	0.80 " 1.10	....	0.20
Wabash Ry..........	70	0.42 " 0.50	0.085	0.75 " 0.98	0.07	0.20
Wabash Ry..........	80	0.47 " 0.55	0.085	0.80 " 1.00	0.07	0.20
Wabash Ry..........	90	0.53 " 0.61	0.085	0.80 " 1.00	0.07	0.20
Wabash Ry..........	100	0.60 " 0.68	0.085	0.80 " 1.00	0.07	0.20
Phila. & Read. Ry....	90	0.53 " 0.63	0.07	0.90 " 1.20	0.07	....
Mich. Cent. Ry.......	80 to 100	0.48 " 0.60	0.10	0.90 " 1.20	....	0.20
Boston Elev. Ry.....	....	0.65 " 0.75	0.06	1.00 " 1.30	....	0.25
British Standards	60 to 100	0.35 " 0.50	0.07	0.70 " 1.00	0.07	0.10
		B. Open-hearth Basic Steel.				
Am. Soc. C. E........	70 to 79	0.53 to 0.63	0.05	0.75 to 1.00	0.06	0.20
Am. Soc. C. E........	80 " 89	0.58 " 0.68	0.05	0.80 " 1.05	0.06	0.20
Am. Soc. C. E........	90 " 100	0.65 " 0.75	0.05	0.80 " 1.05	0.06	0.20
Am. Ry. Eng. Assoc ..	70 " 79	0.63 " 0.73	0.03	0.90*	0.06	0.075 to 0.2
Am. Ry. Eng. Assoc ..	80 " 89	0.68 " 0.78	0.03	0.90*	0.06	0.075 " 0.2
Am. Ry. Eng. Assoc ..	90 " 100	0.75 " 0.85	0.03	0.90*	0.06	0.075 " 0.2
So. Pac. Ry..........	75	0.51 " 0.61	0.06	0.75 " 1.00	0.06	0.20
So. Pac. Ry..........	90	0.58 " 0.72	0.06	0.80 " 1.05	0.06	0.20

Note.—Where no figures are given, the specifications omit reference to these constituents.

* The percentage in these cases must not be exceeded.

† The New York Central Ry. specifies minimum and maximum percentages of carbon, and steel showing lower or higher percentages will be rejected:

Weight of rail	65-lb.	70-lb.	75-lb.	80-lb.	100-lb.
Minimum	43%	45%	48%	53%	60%
Maximum	57%	59%	62%	65%	70%

Many of the heavier modern rails give less wear or service than lighter rails made when the manufacture was more carefully attended to. At one time engineers and rail makers claimed that heavy rails could not be made which would give as good service as the smaller and lighter rails. This, of course, was erroneous, and with the present scientific knowledge and powerful machinery, modern mills can make heavy rails of high quality. But the makers are arbitrary and instead of making rails as required by engineers they prefer to follow

their own specifications, thus dictating the character of the rails. There is also a general tendency to roll the rails too hot and too rapidly, as already noted. Under such conditions a high quality of product is not to be expected. Rail breakages have become increasingly numerous. It is claimed that the breakages and rapid wear are due to increased wheel loads and traffic, but this is refuted by the fact that old light rails satisfactorily carry traffic under which new and heavier rails begin to crush, fail and break as soon as laid in the track. As an instance of many cases, the Grand Trunk Ry. experienced frequent breakages of new 80-lb. rails, while none occurred with 10-year-old 65-lb. rails on the same track. The defective character of modern 80-lb. to 100-lb. rails has been shown by investigation. The coarse grain indicates insufficient work and too high a temperature in rolling, while the combination of high phosphorus with high carbon results in brittleness. This latter feature is one cause for the increasing use of low-phosphorus open-hearth rails. But another serious defect is in the numerous cavities and seams in the metal, which lead to fracture. These result from the use of metal in the ingots which has not properly solidified, due to handling it too soon after casting, or to the use of the spongy metal near the head of the ingot. The cavities in this are rolled out into "pipes" in the rail. To prevent this, engineers have demanded that at least 25% of the head of the ingot should be cropped (or such amount as will give solid metal). This is strongly opposed by the manufacturers, as it would tend to reduce the output, while the cropped ends must be largely remelted. Their quantity would be more than sufficient for light second-class rails, and their quality unsuitable for structural steel. They might be rolled for angle bars (see Joints). The manufacturers, however, have it in their power to make ingots of such quality that such a percentage of discard would not be required; until they do this, the high arbitrary discard should be enforced by the railways.

Methods resulting in improved quality of rails may result in higher prices. The necessity of this is doubtful, as the cost of manufacture has been reduced very low, while the market price has little to do with the quality, being fixed arbitrarily. The ultimate improvement in manufacture may require some change in the rail section, but it would be useless to make such a change unless there can be an assurance that the improved methods will be employed in its manufacture. Nor would heavier rails be of benefit under such conditions. As a matter of fact, the present rails could be made of better quality. A practice at one time obtained by which the makers guaranteed to replace all worn or broken rails that had to be renewed within a certain period (usually five years). No such guarantees are now given, and at most the makers agree to replace broken rails which show actual flaws. The guarantee system has been very generally followed in Europe. It is generally recognized that methods of manufacture should be left largely to the discretion of the maker, the rails being carefully inspected and tested on behalf of the purchaser. Under present conditions there is practically no control of the manufacture; the mills very generally decline to make rails to the requirements of the railways, but furnish those made to the specifications adopted by the manufacturers. Three important points to be enforced in order to obtain good rails are: (1) Sufficient cropping of the top of the ingot to insure sound and solid metal; (2) A shrinkage limit to insure low finishing temperature and sufficient working of the metal in the rolls; (3) Drop tests of sufficient number and severity to detect brittle rails.

Specifications usually allow a variation of 1/64-in. under and 1/32-in. over the

specified height; ¼-in. in length, and sometimes $\frac{1}{16}$-in. in width. Also 0.5% in weight for an entire order. Usually about 10% of the order is allowed to be in lengths varying by even feet down to 24 ft. for 30-ft. rails or 27 ft. for 33-ft. rails. A certain proportion, also, are 29½ or 32½ ft. long for curves. There is also an allowance for the acceptance of second-class rails up to about 5% of the order. The short rails for curves and the second-class rails are distinguished by having the ends painted. Some roads also require first-class rails to be painted (a distinctive color) to indicate that they have been inspected.

Rails are usually tested by the drop test, with a weight falling upon a piece of rail placed with head or base upward on supports 3 or 4 ft. apart. The rail must not break under one blow. The Dudley specifications for the New York Central Ry. require that 90% of the rails must stand without breaking and must show 4% elongation in the inch which is subjected to the greatest tension. Spaces of 1 in. marked on the rail under the point of impact enable the elongation to be readily determined. It is not necessary to show a great deflection, as the test is mainly to discover brittle rails. The practice has been to test one rail for each fifth blow or heat of steel, but the specifications approved by railway and engineering associations call for a drop-test for every blow. The makers object on the ground that as all the metal in the mixer is practically uniform and is sufficient for several heats, one test will show the character of the product. The reply to this is that each blow is likely to receive different treatment in the converter and in rolling, and that very different qualities of rails may thus be produced. The specifications further require that the test must be made on a rail rolled from the top of the ingot, which is the part of inferior quality, as already described. They require a 2,000-lb. weight, with an anvil block of at least 20,000 lbs., and rail supports (on this block) 3 ft. apart. The rail must be from 4 to 6 ft. long, and sustain a blow from the weight falling 18 ft. for 65- to 75-lb. rails, 20 ft. for 75- to 85-lb., and 22 ft. for 85- to 100-lb. rails. If the rail breaks, two other rails from the same blow are to be tested, and if both of these stand the test the rails will be accepted. Some roads require bending tests of two bars poured at the same time as the first and last ingots of each heat. The New York Central Ry. specifies test ingots 2½ ins. square rolled to bars ½-in. square; pieces 18 to 20 ins. long must bend 90° without fracture. The Wabash Ry. specifies 3-in. ingots, 4 ins. long, drawn out by hammering to ½-in. section and bent cold to 90°.

Stresses in Rails.—Owing to the lack of uniformity in the tie supports, rails are subjected to varying and severe strains beyond those due to their acting as girders between adjacent ties. Stiffer and heavier rails distribute the loads over a greater length of track, but under present loads and track conditions rails are required to perform more than their proper duty in acting as girders. A plan proposed to secure uniformity in support and to give lower and more uniform stresses in the rails by placing longitudinal beams under the ends of the ties has been mentioned in Chapter I. For the entire length of an engine and tender the track will be depressed slightly below the normal surface of the rail, with an extra depression under each wheel. In front of the engine, the rail is actually above normal level (due to wave motion). The depression under heavily loaded wheels of modern engines may be ⅛-in. to ⅜-in., partly due to compression of the ballast and roadbed.

An important step in regard to determining the efficiency of rail is the introduction of the stremmatograph, invented by Mr. P. H. Dudley, to determine

and record the fiber stresses in rails under load, and the distribution of these stresses in the rails. This is a matter beyond mathematical analysis. As the load (static or dynamic) is applied, the rails deflect, and there is a compression of the ties, ballast and roadbed, the deflection and compression being naturally greatest under the wheels, or the points where the load is applied. Fig. 36 shows the total depression of track laid with 95-lb. rails and stone ballast, with a locomotive standing upon it. In regard to the rail under a moving load, there is a compression in the head, a tension in the base, and a shearing stress across the rail section at or near the ties which at that instant are bearing the load. The span of the rail deflection under the wheel is usually longer than the tie spacing.

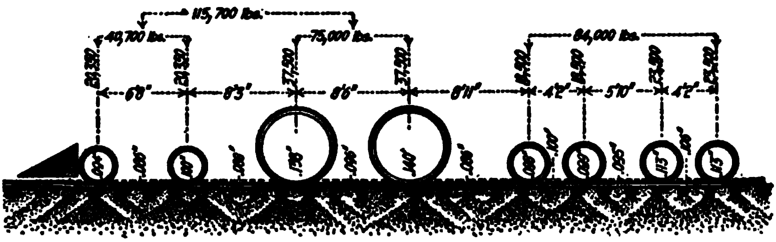


Fig. 36.—Track Deflections under Locomotive and Tender.

At a point a little distance on either side of the wheel the stresses are reversed, the head being in tension and the base in compression.* The tensile fiber stresses per sq. in. in rails of different weights (on stone ballast) under the driving wheels of a freight locomotive, with 113,800 lbs., and a passenger locomotive with 87,300 lbs. on these wheels, were as follows:

	Rails.			
	60-lb.	70-lb.	85-lb.	100-lb.
Freight engine	16,050	11,510	10,030	9,430
Passenger engine	19,540	14,390	10,750	9,840

In a paper presented to the American Institute of Mining Engineers in 1899, Mr. Dudley gave complete records of the stresses in rails under and between the wheels of trains. A brief summary of a record for a train running at 20 miles an hour over 6-in. 100-lb. rails is given in Table No. 6, the stresses being measured on a 5-in. length of one rail.

Wear of Rails.—The life of first-class 60-lb. to 80-lb. steel rails on tangents is given in Wellington's "Economic Theory of Railway Location" (1887) as 150,000,000 to 200,000,000 tons. There are from 10 to 15 lbs. of metal, or ⅝-in. to ¾-in. depth of head, available for wear, and abrasion takes place at the rate of about 1 lb. per 10,000,000 tons, or $\frac{1}{16}$ in. per 14,000,000 to 15,000,000 tons of traffic. The rate of wear is increased locally about 75% by the use of sand by the locomotives. About half the metal in the rail head is available for wear, but this is not obtainable in main track, as the rails would be too rough for service; about ½-in. to ⅝-in. is the limit of wear in main track, the rails being then removed to branch or side tracks. High-carbon 100-lb. 6-in. rails on the New York Central Ry. have carried 250,000,000 tons with a wear of only $\frac{1}{16}$-in. depth of head; while others laid in 1895 had in 1905 carried 275,000,000 tons of heavy wheel loads with a wear of only 3/32-in. in the center of the head. Mr. Sand-

* Engineering News, Oct. 6, 1898; Railroad Gazette, May 20 and Oct. 21, 1898; Feb. 23, 1900.

berg's 100-lb. rails in England, after seven years' service, had carried about 7,000,-000 tons with a wear of 3/32-in. in the head, and he estimated the life at 30,-000,000 tons. Mr. Price Williams, the English engineer, estimates 20,000,000 tons per $\frac{1}{16}$-in. wear for bull-head rails, with a safe limit of wear of $\frac{3}{8}$-in., or a life of 120,000,000 tons. On curves, the life is regulated by the flange wear on the sides of the heads; this varies with the degree of curve, the traffic and the quality of the rail. With rigid or secure fastenings this wear is reduced as compared with that where common spikes are used. In tunnels there is apt to be abnormal wear due to use of sand on damp rails, and also corrosion due to the effect of the dampness, the gases from the engine, and the drippings from coal, ore and refrigerator cars. In some English tunnels the rails are painted.

TABLE NO. 6.—STRESSES IN RAILS.

	Tension. lbs.	Compression. lbs.
In front of first truck wheel	.....	2,362
Under first truck wheel	13,227	.....
Between truck wheels	.....	6,850
Under second truck wheel	7,086	.....
Between truck and driving wheels	.....	5,669
Under first driving wheel	8,267	.....
Between driving wheels	.....	7,086
Under second driving wheel	6,141	.....
Between engine and tender	.....	5,669
Under first tender wheel	4,960	.....
Between wheels	.....	2,834
Under second tender wheel	5,905	.....
Between wheels	.....	5,432
Under third tender wheel	4,448	.....
Between wheels	.....	3,307
Under fourth tender wheel	6,377	.....
Between tender and first car	.....	4,015
Under first wheel of rear car	7,322	.....
Between wheels	.....	3,071
Under second wheel of rear car	3,543	.....
Between wheels	.....	3,071
Under third wheel of rear car	4,017	.....
Behind third wheel	.....	1,417
Between trucks	.....	472
In front of fourth wheel	.....	945
Under fourth wheel	9,684	.....
Between wheels	.....	1,890
Under fifth wheel	7,795	.....
Between wheels	.....	2,834
Under sixth wheel	5,905	.....
Behind wheel	.....	709
Instrument returned to zero.		

Modern rails fail more largely by deformation of section at or near the joints, as well as by abrasion proper. The deformation and crushing are largely due to the driving-wheel loads, the wear from which is estimated at 50 to 75% of the total. Heavy freight engines may have three or four driving-wheel loads of 18,000 to 30,000 lbs. on a length of 12 to 16 ft. of the rail, while passenger locomotives have wheel loads of 16,000 to 25,000 lbs. The area of contact between driving wheels and rails is an oval about $\frac{3}{4}\times1$ in. (or $1\times1\frac{1}{2}$ ins. with worn tires or rails), with an area of 1.07 sq. in. This is for rails of moderate weight, and is probably somewhat greater when the wheels are in motion. The length of the area is less with heavy rails having less deflection, and the area in such cases may be 0.8 to 0.9 sq. in. as determined by Mr. P. H. Dudley. Metal confined in the center of the rail head (at the point of contact) can sustain loads of 150,000 to perhaps 180,000 lbs. without decided flow, being supported by the surrounding metal. Under excessive pressures the metal flows and forms a lip along the edge of the rail. This will be increased where worn wheels concentrate the pressure under the false flange. Serious vertical and lateral bending of the

rails, or even failure, may be caused by "dead" locomotives hauled rapidly in freight trains with the rods taken down; or by running engines with small wheels at excessive speeds. In both cases, the unbalanced forces due to the counterbalance weights in the driving wheels have a powerful and destructive effect upon the rails. The rails may also be injured by the slipping of driving wheels in carelessly starting trains at stations, water tanks, etc.

A peculiar character of rail wear which is experienced in this country and abroad, on street railways as well as on ordinary railways, is the formation of transverse corrugations on the head. These make a rough and noisy track. Various causes have been assigned. Mr. Perroud, Engineer of Maintenance of Way of the Northern Ry. of France, has concluded (after extensive investigations) that they are caused by the vibration of the rails as they leave the rolls. They may be accentuated or diminished under different conditions of traffic. With fast trains, the wheels strike a series of sharp blows on the faces of the corrugations, causing very hard spots which cannot be smoothed off, and the result is a noisy track, with increased maintenance due to the effect of the shock and vibration on the ballast. The corrugations are 1.18 to 1.57 ins. c. to c. and 0.0078 to 0.0118 in. deep. The remedy suggested is to face or finish the rolling surfaces of such rails, preferably before they are put in the track. In England, grinding machines are extensively used on street railways to face rails (in the track) which have developed these corrugations.

Special Steel for Rails.—Experiments with grades of hard steel to obtain high wearing quality have not proved successful as a rule. Nickel steel has been tried, but with varying results. The Pittsburg & Lake Erie Ry. laid 50 tons of 90-lb. rail on a 6° curve; no cutting, bending or drilling was done in the track. There were no fractures, and the rails lasted twice as long as ordinary high-carbon rails, but the cost ($35 per ton) was 2½ times that of Bessemer rails. This was not considered justifiable by the results, the wear being irregular, as the nickel was not uniformly distributed. Thus the signal repairmen in drilling for rail bonds found them in some places little harder than ordinary, while in other places 17 drills were broken in making one hole. The cost of this work was about four times that on ordinary rails. About 50 tons were laid in November, 1897, in single track on the Cleveland & Pittsburg Ry., on a curve of 4½°, and after two years' service showed less wear than the ordinary rails. In July, 1899, the Pennsylvania Ry. laid about 220 tons of 100-lb. rails (of the Am. Soc. C. E. section) on the Horseshoe curve. In manufacture, the nickel caused red shortness to such an extent that the rolling of 300 tons resulted in only 220 tons of No. 1 and 57 tons of No. 2 rails, while 19 tons of the latter had to be rejected on account of "piping." The rails showed great rigidity under the straightening press, double the ordinary pressure being required for cold straightening, and the rails would often spring back, showing no effect from the blow. The steel was so hard that five twist drills were sometimes required in drilling one hole, and the best results were obtained by the use of Mushet steel drills without lubrication. The service results are not considered satisfactory. The analyses were as follows:

	Carbon.	Phos.	Manganese.	Nickel.	Silicon.	Sulphur.
Pennsylvania Ry.	0.504	0.094	1.00	3.229	....	....
Cleve. & Pitts. Ry.	0.530	0.014	0.80	3.520	0.048	0.021

Two 70-lb. Harveyized steel rails on the Delaware, Lackawanna & Western Ry. were removed after about 6 years' service, as pieces began to break out of the head without showing any previous crack. The rails were 4½ ins. high, with 5

ins. base, and had worn down ¼-in. when removed. By this process additional carbon is absorbed by the head after the rail is made; an analysis showed 0.76% for $\frac{1}{16}$-in. depth of the head, 0.42% at ⅛-in. and 0.3% at $\frac{3}{16}$-in. Manganese-steel rails have been tried experimentally, particularly on sharp curves (of 82-ft. radius) on the Boston Elevated Ry. Here ordinary rails wore out in about 44 days, with a vertical wear of 0.05 to 0.065 ft.; rails of specially hard steel, 0.015 ft. in 204 days; nickel steel, 0.044 ft. in 204 days. Manganese rails showed only 0.016 ft. wear in 1,000 days and 0.034 ft. in 1,892 days, and were still in service. There was, however, more side wear than top wear, the steel not resisting the cutting action of the wheel flanges so well as the ordinary steel. These rails are cast (not rolled) and are in 20-ft. lengths. They have from 12 to 15% manganese and less than 1% carbon. They are hard and tough, and cannot be cut or drilled in the track, on account of the time and special appliances required. They can be bent, but require more power than Bessemer rails. The castings have to be finished by grinding (nearly all over), to make them uniform in section and to give the proper fishing angle. The holes for joint bolts, guard-rail bolts, electric bonds, etc., all add to the cost, and the cost is from 10 to 15 times that of rolled Bessemer steel rails of the same section.

Rerolled Rails.—In worn rails no longer fit for service, the proportion of metal lost by wear is comparatively small, and the bulk of the metal represents scrap. The McKenna process for rerolling such rails to produce new rails of somewhat lighter weight has been extensively used. The burr or fin on the outside of the rail head is first ground off and the rail is then heated in a reverberatory furnace to about 1,500° or 1,700° F., care being taken that the heat is not sufficient to affect the chemical composition of the rail. The rail is then passed through two sets of rolls, which reduce it to a symmetrical section, while the quality of the steel may be improved by the extra working. The rails are, of course, elongated by rolling, so that 30-ft. rails of the lighter section may be made. They are then sawed, straightened and drilled in the usual way. Old 75-lb. rails, reduced to 73 lbs. by wear, have been rolled to form new 69-lb. rails, and the new Hunt 100-lb. section is designed with a view to this treatment, as already noted.

Trimmed Rails.—Many rails are taken out of main track on account of the bending and wear at the ends. These may be made available for use by cutting off the ends and redrilling. After the rails are cut they are calipered as to height and sorted in groups varying by $\frac{1}{32}$-in., so as to form an even track. For handling rails in this way, several roads use special cars which are hauled to the various division points, thus avoiding transportation of rails. The car is 60 ft. long, with a steel frame. The equipment includes a 42-in. circular saw, straightening press, and two double or triple rail drills, 34 ft. apart. The rails are taken from cars or piles at one side of the machine, and are handled by pneumatic goose-neck cranes. Eight holes (two rails) can be drilled at one time, making the drilling capacity equal to the sawing capacity. From 400 90-lb. rails to 600 75-lb. rails can be treated in a 10-hour day.

Rails for Curves.—It has been explained that the Am. Soc. C. E. section was specially designed for the tangents and easy curves which make up by far the greatest proportion of the railway system. They are successfully used also on sharp curves, but a modified section was designed by W. T. Manning to give a longer life on curves. As in the Vietor rail (tried in Germany) the head was unsymmetrical, about ¼-in. in width being added to the gage side. The top corner radius was $\frac{5}{16}$-in.; but the gage side was vertical for only ¼-in. below this,

being then curved inward with a radius of 1 in. This was to prevent a full flange bearing when worn, which would invite derailment with sharp flanges. An 88-lb. Manning rail was tried on 3° to 10° curves of the Baltimore & Ohio Ry. It was similar to the Am. Soc. C. E. 85-lb. section, but with 0.24 sq. in. of extra metal available for wear. An increased life and decreased cost of maintenance were noted (with no allowance for extra cost of rail or for royalty), but the results were not such as to warrant the further use of the rail. Ordinarily, worn rails on curves are transferred to the opposite side of the track. In orders for rails a certain proportion are required to be 6 ins. short, to be placed on the inside of curves. These have the ends painted to distinguish them.

Double-Head Rails.—In Europe, the double-headed reversible rail, carried in cast-iron chairs, was early designed, but the indentation of the lower head by the chairs made the reversed rails very rough and liable to break. In 1858, the bull-head rail was introduced, having the lower head only large enough to give a seat in the chair and a hold for the wooden "key" or wedge which secures the rail in the chair. This (Fig. 37) is now the standard in England on main lines

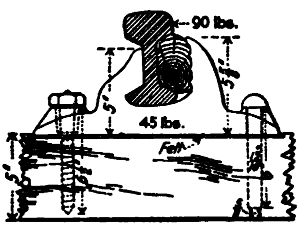


Fig. 37.—Bull-head Rail and Cast-Iron Chair; London & North-western Ry. (England).

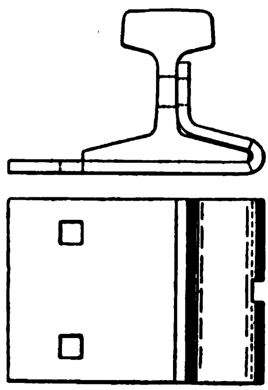


Fig. 38.—Check Plate or Creeper Plate.

and is used to some extent in other countries. One of the great objections is that it has to be held by two heavy cast-iron chairs (26 to 56 lbs. each) on every tie. The wear at the chairs often limits the life of the rails, being even more than at the joints. They have one advantage, however, in giving a good support against lateral thrust on curves. Some of the rails have rounded heads, while others have vertical sides and sharper top corners. In the British standard sections adopted in 1905, the heads have vertical sides and a top and bottom radius of 12 ins., with fishing angles of 20°. The top corner radius is $\frac{3}{8}$-in. for 60- to 80-lb. rails, and $\frac{1}{2}$-in. for 85- to 100-lb. rails. The distribution of metal varies with the different weights: it is 46.4, 21.8 and 31.8% for the head, web and base of the 60-lb. section; 50.12, 20.05 and 29.83% for the 100-lb. section. Flat splice bars are generally used with these, but in some cases they have curved lower flanges extending under the lower head. In England the erroneous idea still prevails that a T-rail track is necessarily unsafe. This in earlier days even led to the use of double-head rails for colonial railways, involving much unneces-

sary expense which might have been applied to the construction of a greater mileage of the more suitable type of T-rail track now almost universally adopted.

Compound Rails.—Various forms of compound rails have been designed to enable the wearing part of the rail to be renewed. They have failed owing to faulty connections or too great complication and consequent cost. In some cases the head was divided vertically, but in most designs the head was complete in itself, and detachable from the web or base. A flangeless T was a favorite form for the head, with the stem fitting into the grooved web of the base, or between two longitudinal angles. The cost of manufacture would be practically prohibitive. As the small contact surfaces would not suffice to resist the strains imposed by modern loads, wear would soon result, with consequent rattling of the track.

Expansion of Rails.—At the joints a space is left between the ends of the rails to provide for the expansion and contraction of the metal. If this is not done, or if the bolts are screwed up so tightly that the rails cannot slip in the splice bars, then in very hot weather the track may buckle to such an extent as to delay traffic or cause an accident. On a curve the line may be thrown out, so as not to be very noticeable, but on tangents the whole line, rails and ties together, may be thrown out in a bow, or arched up from the ballast. The spacing is provided for in tracklaying by means of strips of iron of proper thickness placed between the rails as they are laid. (See Tracklaying and Laying Rails.) The coefficient of linear expansion of steel for 1° F. is given by Prof. Merriman in his "Mechanics of Materials" as 0.0000065. The expansion (in inches) of a 30-ft. rail for one degree increase in temperature would therefore be $0.0000065 \times 30 \times 12 = 0.00234$. In Table No. 7, compiled by Mr. W. C. Downing, of the Vandalia Line, is given the variation in length of a 30-ft. rail for each 10° increase in temperature from −30° F. to +130° F., the rails being assumed to be in contact at the latter temperature:

TABLE NO. 7.—EXPANSION OF STEEL RAILS.

Temperature.	Variation.		Thickness of exp. shim.	Temperature.	Variation.		Thickness of exp. shim.
−30°	0.3744 in.	24/64 in.	6/16 in.	60°	0.1638 in.	10/64 in.	3/16 in.
−20°	.3510 in.	22/64 in.	6/16 in.	70°	.1404 in.	9/64 in.	3/16 in.
−10°	.3276 in.	21/64 in.	6/16 in.	80°	.1170 in.	7/64 in.	2/16 in.
0°	.3042 in.	19/64 in.	5/16 in.	90°	.0936 in.	6/64 in.	2/16 in.
10°	.2808 in.	18/64 in.	5/16 in.	100°	.0702 in.	5/64 in.	1/16 in.
20°	.2574 in.	16/64 in.	4/16 in.	110°	.0468 in.	3/64 in.	1/16 in.
30°	.2340 in.	15/64 in.	4/16 in.	120°	.0234 in.	1/64 in.	1/16 in.
40°	.2106 in.	14/64 in.	4/16 in.	130°	.0000 in.	......	......
50°	.1872 in.	12/64 in.	3/16 in.				

There has been much discussion as to the expansion of 60-ft. rails and heavy rails. Where heavy rails reach the same temperature as lighter rails the expansion will be the same, but as the heavier rail takes a longer time to absorb the heat, and as the time of exposure to great heat is short, the practical result is that a smaller amount of expansion spacing is required. On several roads, therefore, less expansion (about half the theoretical) is allowed for heavy rails. These rails are also sometimes laid in contact in warm weather, as it is found by experience that they expand less than lighter rails even in hot summer weather. Most roads vary the spacing by 1/16-in. The Southern Pacific Ry. uses 1/64 and the Illinois Central Ry. uses 1/32-in.; the latter uses 33-ft. rails, and requires that the spacing shim must be left out of every 11th joint with 30-ft. rails, every 7th

with 28-ft., and every 5th joint with 26-ft. rails. The Pennsylvania Lines require that in tunnels at above 70° the rails are to be laid close, without bumping; below 70° F., a spacing of 1/16-in. for each 24° of temperature. The Missouri Pacific Ry. has a similar rule, except that it is 1/16-in. for each 15° for 60-ft. rails, and for each 25° for 33- and 30-ft. rails. The spacings specified by different railways are given in Table No. 8. Above the maximum temperature the rails are laid close, without bumping.

TABLE NO. 8.—EXPANSION SPACING FOR 30-FT. AND 33-FT. RAILS.

	Temperature: degrees Fahr.					Southern Pacific Ry.		
Spacing. ins.	C. M. & St. P. Ry.	Penna. Lines.	Mich. Cen. Ry.	Boston & Me. Ry.	West. Pac. Ry.*	Degrees Fahr.	Spacing.	M. M. dec. gage.
5/16	Below 0	−10 to 14	7 to 30	......	to −2	0 to 32	1/4 in.	0.250
1/4	0 to 25	14 " 38	30 " 53	30 to 45	24	32 " 50	7/32 in.	0.220
3/16	25 " 50	38 " 62	53 " 76	45 " 60	50	50 " 70	3/16 in.	0.200
1/8	50 " 75	62 " 86	76 " 97	60 " 75	76	70 " 90	9/64 in.	0.150
1/16	75 " 105	86 " 110	97 " 120	75 " 90	102	90 " 110	3/32 in.	0.095
						110 " 130	3/64 in.	0.045
						130 " 150	.0	0.000

* 3/8-in. for below −28° F.

Creeping of Rails.—In many places the rails develop a tendency to creep or travel along the track, both up and down grade, either with or against the traffic. This is due to a combination of the effect of wave motion in the rail and track, unbalanced traffic in one direction, the action of braked wheels, the contraction and expansion incident to changes in temperature, etc. (See "The Creeping of Rails," by S. T. Wagner, Transactions, Am. Soc. C. E., 1904.) It is a phenomenon of frequent occurrence, especially with light rails on a lightly ballasted track carrying heavy traffic. It is apt to cause trouble at track crossings, frogs and switches, and bridges (especially drawbridges). The creeping of track (rails and ties together) occurs sometimes on swampy roadbed, owing to the wave motion under traffic. To resist this on a track used by consolidation engines with a weight of 120,000 lbs. on the driving wheels, the Minneapolis, St. Paul & Sault Ste. Marie Ry. used ties 10 and 12 ft. long, with angle bars spiked to two ties at the center of the rail to keep the rails from creeping on the ties. Many curious instances of creeping are familiar to trackmen and engineers. In general, rails are allowed to creep on bridges, and the joints are not slot-spiked, so as to avoid throwing undesirable strains upon the structures. If the creeping is to be checked, blocking should be placed between the ties. The abnormal creeping on the Eads bridge over the Mississippi River at St. Louis has been carefully observed for some years. The flexibility of the steel arch ribs under traffic accentuates the elasticity of the track. Means are therefore provided to allow the rails to creep, and as there are two double crossovers which must be maintained in place, eight creeping places are established. Two switch points are placed in the track, and the main rails pass outside the switch rails, which are firmly anchored to steel plates on the ties and have guard rails on the inside with a flangeway of 2 ins. When a rail has nearly pulled past the switch points, another is coupled on, while a rail that has pushed through is uncoupled and taken back to the other end of the section. From November, 1899, to July, 1900, the creeping per month on the bridge proper was as follows, the maximum being in the summer, as a rule:

	North rail.	South rail.
Inbound track	9 ft. 2 ins. to 23 ft. 4 ins.	9 ft. 3 ins. to 26 ft. 3 ins.
Outbound track	9 ft. 3 ins. to 28 ft. 8 ins.	3 ft. 0 ins. to 42 ft. 3 ins.

To provide against ordinary creeping, the flanges of angle bars have slots in which the spikes are fitted. Narrow bars do not give much hold for the spikes,

which are likely to be crowded out of the slots, leaving the rails and bars free to creep. Wide-flanged bars are the best, with slots about ⅞-in. deep, but bars having holes instead of slots are still better, as they cannot get away from the spikes. It is bad practice to slot the rail base for spikes. Heavy rails, good fastenings and substantial track usually give much less trouble than light track, and any ordinary creeping can usually be avoided by the use of heavy rails and carefully spiked angle bars. Where special trouble is encountered, each rail may be anchored at the middle by means of a creeper plate or check plate, as in this way the motion of each rail is independent and not cumulative. A combined tie-plate and check-plate used at the middle of each rail is shown in Fig. 38. It has a bolt through the rail, and is spiked to the tie. The Boston Elevated Ry. uses anchor plates bolted to the rails and spiked to the ties, being made to fit the rail and tie-plate. The Chicago, Burlington & Quincy Ry. uses two pieces of angle bar 5 ins. long, bolted to the middle of the rail and spiked to the tie. Similar plates, used singly or in pairs, are used to prevent creeping at grade crossings. The various devices for the purpose of holding the rails include different arrangements of clamps attached to the rail base and bearing against the side of a tie. They avoid the necessity of drilling or punching holes in the rail. One of these has a pair of clamps, the jaw gripping the edge of the rail base being serrated so as to get a good grip and prevent the rail from slipping through. The clamps are drawn tight upon the rail by a bolt passing under it. Other devices fitting under the rail have one end hooked over the rail base, while the inner end has a bolted clamp or the plate is extended up to fit against the splice bar, being secured by one of the splice bolts. In some of these, the clamp is set slightly diagonal to the rail so that any tendency of the rail to slip through it only gives a tighter grip. A device for use with three-tie joints is a plate so shaped that the part lying on the tie has the end bent up to fit against the angle bar (at one of the bolt holes), while the side is bent down to bear against the side of the tie. At a double-track crossing, the north and southbound tracks moved north and south respectively about 2½ ins. per month. Each time of straightening the crossing cost about $95; but with an expenditure of $6 for creepers the track was held permanently. (See also Expansion Joints, in the next chapter.)

CHAPTER 6.—RAIL FASTENINGS AND RAIL JOINTS.

One of the weak points of the track is in the fastening of the rails to the ties, for in spite of the increase in weight of rail and the enormous increase in wheel loads, train loads, traffic and speed, the almost universal fastening is still the ordinary spike developed from the Stevens hook-headed spike of 1830. This was an excellent device in its day, and is still suitable for light rails carrying light rolling stock and traffic, but it is unsatisfactory and uneconomical for first-class modern track, with 80- to 100-lb. rails, carrying heavy traffic and the great weights of modern locomotives and trains. Comparatively little attention has been paid to the question of improved fastenings, although many forms have been designed and some have been tried experimentally, while the defects of the spike have frequently been pointed out. It is most desirable for safety and for economy in maintenance, that some more efficient fastening than the spike should be generally

adopted, but at the present time the maintenance-of-way department has, as a rule, only the spike to consider, and must make the best of it. For heavy track, a fastening should be adopted which will give a positive hold on the tie, and not merely the frictional hold of a spike. Experience with steel ties on the Bessemer & Lake Erie Ry. and Lake Shore & Michigan Southern Ry. indicates less wear of rails on curves due to rigid and secure fastenings.

The spike is simply a large nail, and depends solely upon the friction of the fibers of the wood for its hold in the tie. Newly driven spikes in good ties have a tolerably good hold, but this is rapidly reduced by the constant vibration and working of the rail under traffic, and by the "spike killing" of the tie by the continual working up and driving down of the spikes. The spike being held by friction only, the vertical wave motion of the rail under traffic gradually draws it out, while the lateral thrust on the rail by the wheel flanges (especially on curves) tends to tilt the rail outwards, drawing the inner spike up and pressing the outer spike back into the wood. This crushes the fibers and enlarges the spike holes, besides wearing and abrading the neck of the spike. The great advantages of tie-plates in preventing the "necking" of the spikes have already been pointed out. Boring holes for the spikes would prevent much cracking and checking of the wood, and holes of diameter $\frac{1}{16}$-in. to $\frac{1}{8}$-in. less than the side of the spike would increase the holding power.

The common spike shown at A, Fig. 39, is $5\frac{1}{2}$ ins. long under the back of the head, 6 ins. long over all, $\frac{9}{16}$-in. square, with the end wedge-shaped for about $1\frac{3}{4}$

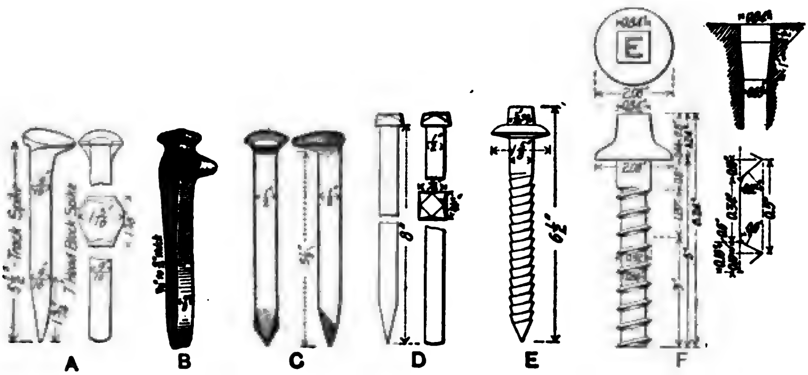


Fig. 39.—Rail Fastenings, Spikes and Screws.

ins. and terminating in a blunt chisel edge. Spikes of greater length are rarely used, except with shims. Spikes weigh about $\frac{1}{2}$-lb. and are put up in kegs of 200 lbs. A keg contains about 450 to 475 spikes $\frac{1}{2}\times 5$ ins., or 360 to 375 spikes $\frac{9}{16}\times 5\frac{1}{2}$ ins., the length being measured under the head. They have usually rough surfaces and blunt points, which crush and tear the fibers of the wood to a degree depending in part on care in driving. A great improvement may be effected by the use of spikes having clean and even (not smooth) surfaces, sharp edges and sharp points, so that the fibers will not be torn, but will be cut by the sharp point, and pressed back and downward by the body of the spike. The fibers thus tightly compressed, with their ends slightly bent down against the faces of the spike, offer a strong resistance to pulling and tend to prevent the entrance of water. Various forms of spikes have been devised, some with

twisted, grooved or jagged faces, but extensive experiments have proved that it is not easy to increase the holding power of a well-made common spike. The head may be improved by making it larger and heavier, and in one form the head is much deeper than usual, but flush with the back of the spike, the top surface curving down to the rail and the head projecting farther than usual over the rail base. Spikes used on foreign railways, where they are sometimes used alternately with screws or bolts, have usually larger and heavier heads than American spikes. Thus, some $\frac{5}{8}$-in. spikes have heads 1 in. wide (lengthwise of the rail) and extending $\frac{5}{8}$-in. over the rail base.

In the Goldie spike (C, Fig. 39) the end is ground to a sharp point, instead of to a chisel edge, while both edges and faces of the point are inclined so as to increase the cutting and wedging effect. The body is the same size all the way down to the point, and is made with clean surfaces and sharp edges. Some spikes have a bayonet groove in the back of the lower portion, the face being convex; the point is sometimes ground to a sharp edge, and may be convex for cedar ties and concave for oak or hard ties. The Greer spike (B, Fig. 39) is of varying section, $5\frac{1}{2}$ ins. long, $\frac{7}{8}$-in. wide and $\frac{5}{16}$- to $\frac{9}{16}$-in. thick. The swelling shape is claimed to increase the grip of the fibers, while the unusual width gives greater resistance to lateral thrust. Longer spikes are used for headblock chairs, and for crossing planks. The crossing spike (D, Fig. 39) is $\frac{1}{2}$-in. square and 8 ins. long under the head, which is $\frac{3}{4}$-in. square. Boat spikes are better and cheaper than track spikes for fastening the planks of highway crossings. These boat spikes are usually $\frac{5}{8}$-in. square and 7 or 8 ins. long. Where spikes are driven into longitudinal timbers, as in some cases on bridge floors, they are made with the chisel edge reversed, being at right angles to the rail so as to cut across the fibers of the wood, as in cross ties. Good spikes are made of soft steel with an ultimate tensile strength of 55,000 to 65,000 lbs. per sq. in., and an elongation of 25% in 8 ins. The Baltimore & Ohio Ry. requires spikes of this kind and specifies the following tests: (1) Spike bent 180° flat on itself without fracture; (2) Spike twisted two full turns; (3) Head flattened in one blow of a steam hammer without fracture; (4) Spike driven home in a white-oak tie, with head on rail, and then struck a blow with a spiking hammer sufficient to drive it further into the tie and bend the head slightly upward without sign of fracture.

Tests of Resistance of Spikes.—Numerous experiments made on the holding power of spikes show that there is a great variation, due to the kind and condition of the wood and the quality of the spike. As an average, a well-made $\frac{9}{16}$-in. spike, newly driven in a good oak or pine tie, may be assumed to have a resistance to pulling of 3,000 to 3,500 lbs., which is reduced when the spike has once started. Resistances up to 7,000 lbs. have been recorded, but cannot be considered as obtaining in ordinary conditions of track and spiking. The testing machine exerts a steady pull upon the spike, but the rail exerts an irregular and jerking pull, which, with the leverage due to wave motion and lateral thrust of the rail, all tend to loosen the spike. In inferior woods, the initial resistance may be only 1,800 to 2,000 lbs. The upward pull exerted by the rail under the influence of traffic very soon begins to lessen the resistance, and spikes redriven in their own or other old holes have the holding power reduced by 20 to 50%. Lag screws, or screw spikes, under ordinary conditions, may be assumed to give a resistance of from 5,000 to 9,000 lbs. in oak, or from 4,000 to 7,000 lbs. in pine. This is maintained for a much longer time than with ordinary spikes, being due to the mechanical bond of the thread in the wood instead of the

mere surface friction. In knotty ties, the resistance is less than in new ties for spikes but greater for screws.

The tendency of wheel pressures to force the rail outwards, especially on curves, has already been noted, and its effect is to crowd back the spike, enlarging the hole and so reducing the grip in the wood. To determine the effect, impact tests have been made with a 100-lb. hammer on a pendulum rod, falling 1½ ft. and striking a bar fitted against the neck of the spike. Five blows were delivered in each case, and all the spikes were bent to a curve whose central point was about 1½ ins. below the top of the tie. The ordinary spikes were slightly pulled out, but in screw spikes the hold of the thread prevented this. The use of tie-plates (properly punched) increases the lateral resistance by distributing it over the inside and outside spikes, but these were not included in the tests. The results were as follows:

	White oak.	Water oak.	Black oak.	Elm.	Beech.	Chest-nut.	Pine.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1st blow: common spike	0.21	0.19	0.21	0.22	0.25	0.32	0.22
1st blow: screw spike	0.09	0.09	0.11	0.17	0.14	0.16	0.21
Total common spike	0.70	0.76	0.71	0.69	0.84	1.23	0.69
Total screw spike	0.39	0.41	0.43	0.70	0.51	0.56	0.79

Screw Spikes.—These have long been common in foreign practice, sometimes holding the rail direct by the spike head, and sometimes by means of a clamp, as in Figs. 23 and 24. They usually have a small projection or a number in relief formed on top, so that it will at once be evident if the spike has been driven home with a maul, this being strictly forbidden. On railway bridges, T-rails and bridge rails are often secured to longitudinal timbers by screw spikes placed against the rail base, or through holes in the base, the spikes being at such an angle that the heads have full bearing on the rail base. The holes are often drilled by crank augers, without the use of guides, and the spikes are screwed in by socket wrenches. In cross ties, the holes are often bored by machinery, but this is not always practicable, owing to the varying widths of rail base. The screw spikes of the Netherlands State Railways (Fig. 24) are 7.5 ins. long over all, 5.56 ins. under the head, 0.57-in. diameter in the shank and 0.89-in. over the threads, which have a pitch of 0.84-in. The mushroom head is 2 ins. diameter, with a tapering projection, 0.84 to 0.92-in. square, for the socket wrench. Fig. 39 (F) shows the screw spike of the Eastern Ry. of France, and the form of thread. A V-thread with ½-in. pitch is found to be the best. Threaded spikes were first used in Germany about 1860, but these had a thread of long pitch and were driven in the same way as common spikes. A threaded drive spike has been tried to a small extent in this country (E, Fig. 39). Screw spikes proper were tried on the Kansas Pacific Ry. in 1870, and on the Pennsylvania Ry. and New York Central Ry. about 1890. In the screw-spike fastening devised by Mr. Katte when Chief Engineer of this last road, the spikes were slightly inclined under the rail (being perpendicular to the upper face of the rail base) and held the rails by clamps. Such fastenings have been very little used in this country, although they are now being tried experimentally on several railways. Their most extensive use is on the South Side Elevated Ry., of Chicago, where they are the standard fastening. They are 6½ ins. long over all, and 5¼ ins. under the head, with 4¼ ins. threaded. The diameter is ⅞-in. in the shank, and the V-thread is ⅛-in. deep, leaving ⅝-in. at the root. The mushroom head is 2 ins. diameter, with a square projection for the wrench. Tests made with these spikes screwed

into holes $\frac{5}{8}$-in. diameter (the diameter at the root of the thread) gave average resistances as follows:

	Loblolly pine. lbs.	Chestnut lbs.	Long-leaf pine. lbs.	Oak. lbs.	White oak. lbs.
Screw..............	8,504	9,418	10,558	11,240	13,026
Spike..............	3,474	2,980	2,296	4,342	6,950

The spikes may be screwed in by a long cross-handled socket wrench; electrically operated machines (like electric drills) have been employed, and also a machine in which the socket wrench is carried in a tripod resting on the rail and tie and driven by gearing operated by crank handles. (Engineering News, Aug. 25, 1904.) A few weeks after the spikes have been applied, it will be necessary to tighten them up, as the wood compresses and the rails and tie-plates settle into place. After this they require very little attention. It is a little more trouble, of course, to bore a hole in a tie, dip a screw spike in paint or tar, and screw it into the hole, than to drive in an ordinary spike. But the first process leaves the tie practically uninjured, while the second process so bruises and crushes the fiber and so imperfectly fills the hole that water will sooner or later find access. With proper tools to set the screw spikes, the additional labor in placing them should count for little in view of the results obtained. It has been claimed that a screw spike has such a firm hold in the tie that with lightly tamped track it will not pull or "give" as a common spike does, but will raise a low tie from its bed and cause pumping of the ballast. This might be an objection on light and poorly maintained track, but does not apply to railways of heavy traffic where good track is required. The secure fastenings also have a tendency to reduce the rail wear.

The increase in efficiency of the screw spike is aimed at by the Thiollier fastening. After the hole has been bored, it is tapped with a spiral groove to a certain depth, and a steel helix or spiral is screwed into this hole, the normal pitch of the spiral being greater than that of the thread. The screw spike is then inserted and screwed home, its sharp thread cutting into the wood compressed between the coils of the spiral. This is a French device and is being tried on the Pennsylvania Lines, in conjunction with flat tie-plates. The spike is $6\frac{7}{8}$ ins. long over all, $\frac{1}{2}$-in. diameter in the shank, 13/16-in. under the head and over the thread. The V-thread is $\frac{1}{8}$-in. wide, with a pitch of $\frac{1}{2}$-in. The Lakhovsky device is for the same purpose, and has also been tried in France. On the spike is fitted a split sleeve with a thread on the outside, and a conical nut fits into the bottom of this sleeve. The spike hole is enlarged for 75% of its depth, and when the device is dropped in the nut rests at the bottom of the hole. The spike is then screwed down into the lower part of the hole, causing the nut to rise and (by wings on the sides) spread the sleeve so that its thread is forced into the wood. A number of European railways have experimented with dowels or plugs of hard wood (creosoted beech, $1\frac{1}{2}$ ins. diameter) inserted into round or threaded holes in soft wood ties. The plugs are hollow and screw spikes are screwed into them. They can be renewed when worn, but fit so tightly as to prevent water from entering in around them. They increase the resistance of the spike about 30% in new pine ties; and in old ties from 33% for beech, 60% for oak and 80% for pine.

Bolts.—Bolts are not used in this country for fastening rails to wooden ties, but are used with steel ties and also on bridges where the rails are laid directly upon an unballasted steel floor. Those for steel ties are usually $\frac{3}{4}$-in. or $\frac{7}{8}$-in.

diameter, with the head inside or under the flange of the tie; the nut screws down upon a clamp which holds the rail base (or splice bar). The clamp may have the rear end made to fit into the hole in the tie, thus giving a better bearing for the bolt; it usually allows for making slight changes in the gage on curves or for adjusting worn rails. The fastening for the Carnegie tie is shown in Fig. 25. The Campbell concrete tie has a $\frac{3}{4}$-in. U-bolt for each rail, the bottom being diagonally across the tie, while the ends pass through holes in the tie and through diagonally opposite corners of the tie-plate. On bridge floors, there are usually two ordinary bolts, but the Chicago, Milwaukee & St. Paul Ry. uses U-bolts, with a saddle on the horizontal member, and a nut and clamp on each end. Such fastenings may be insulated by laying the rail on a strip of insulating material and placing washers of similar material between the rail and the clamps.

In foreign practice, fang-bolts are largely used, the head bearing upon a clamp or directly upon the rail base, while the threaded end passes through a large nut under the tie. This nut has fangs or projections to bite into the wood and prevent the nut from turning as the bolt is screwed down. In the author's paper on "The Improvement of Railway Track" (Transactions of the American Society of Civil Engineers, March, 1890) it was suggested that a better plan would be to have the head of the bolt underneath, using a fang washer with ribs to prevent the turning of the bolt as the nut is screwed on, as shown at (A), Fig. 24. It would be practicable to form the fangs on the corners of the bolt head. Renewals of any through bolts are somewhat difficult, ballast having to be cleared away more or less, but such renewals are much less frequent than with spikes.

Wedges.—Steel wedge or key fastenings are shown in Figs. 24 and 28, and a wooden wedge fastening in Fig. 37.

Rail Braces.—The lateral thrust on the rails at curves, turnouts, etc., is very severe, and the outer spikes are very generally reinforced by braces which are spiked to the tie and bear against the side of the rail, thus taking the outward thrust. Guard rails and the lead rails of turnouts are also reinforced by braces. Unless the braces are well designed and well looked after, their value will be very considerably reduced by the outer edge of the rail base cutting into the tie, the load being thus thrown on top of the brace and tending to raise its heel. To prevent this, a combination of tie-plate and rail-brace has been designed. The box brace in Fig. 40 is of pressed steel, $\frac{1}{4}$-in. to $\frac{5}{16}$-in. thick, and supports the

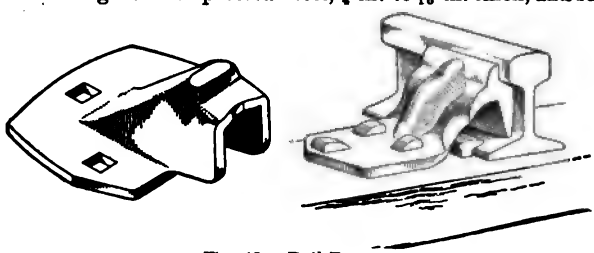


Fig. 40.—Rail Braces.

rail head from below as well as at the side. The box fits over the rail spike. Another rail brace, of different design, is also shown. Almost any form of metal tie-plate will give increased safety and economy by preventing the cutting of the tie and the tilting of the rail, and such plates are often used instead of braces.

The number of braces to each rail depends upon the sharpness of the curve. The Louisville & Nashville Ry. requires two braces on every fourth tie on curves

of 4° and 5°, and on every third tie of curves of 6° and over. On the Southern Pacific Ry. they are used for both rails on every fourth tie for curves of 4° to 7°, every third tie to 8½°, and on alternate ties up to 10°. This is only where tie-plates are not used on all ties. Some roads specify three braces (at center and quarters) per rail on 5° curves with oak ties, and on 3° curves with cedar or other soft ties. The braces must be on the inside and outside rails, and placed on the same tie for both rails. Sometimes only the outer rail is braced, but generally the inner rail also, so as to resist the thrust due to slow heavy trains, and also to relieve the outside spikes of the inner rail from the lateral pull of the tie due to wheel pressure against the outer rail. Guard rails at frogs should have two to four rail braces, according to length, unless these rails are clamped or bolted to the track rails.

Tie Bars.—Tie bars or bridle rods are used to hold the rails to gage at switches. They might be more extensively used for the same purpose on curves and where track is raised by shimming. One arrangement used in the latter case consists of two flat bars having one end bent to engage the outside of the rail base, while the inner end is forged into a round rod and threaded; the two parts are connected by a turnbuckle. For sharp curves in terminal yards, the Chicago & Northwestern Ry. uses flat bars bent up at each end to fit over the rails. In European practice the ends of the rods on bars are sometimes passed through the webs of the rails and secured by nuts, as in street-railway track.

Check Plates.—These are used to prevent creeping of the rails upon the ties, and have been described in the chapter on "Rails."

Rail Joints.

The rail joint has received very much more attention than the rail fastening, for weak joints cause a roughly riding track and a more apparent wear of the rails, the economical necessity of providing against which is more in evidence than that of the effects of inefficient fastenings. Good results cannot be expected from any style of joint unless it is properly maintained. In fact a better track may be maintained where the section foreman is a little anxious about his joints, than where he has new joints which he considers can be left to take care of themselves. A well spliced joint will require a minimum of expense and labor for maintenance. On many roads a considerable proportion of the maintenance work is expended in tightening bolts, raising low joints and other work at this part of the track.

The difficulty of making and maintaining an efficient joint will be understood if the work which it has to do is considered. It has to hold together, vertically and horizontally, the free ends of two independent rails which are subjected to very varying strains. At one extreme are the strains due to the hammer-like blows delivered by fast trains drawn by engines with driving-wheel (static) loads of from 20,000 to 25,000 and even 30,000 lbs. per wheel, followed by a series of rapid blows from car wheels carrying from 4,000 to 8,000 lbs. each. At the other extreme are the strains due to the pounding of slow heavy freight trains, drawn by engines having three or four driving-wheel loads of from 20,000 to 30,000 lbs., and followed by 120 to 200 car wheels with loads varying from 3,500 to 18,000 lbs. per wheel, aggravated perhaps by flat or worn wheels. For a perfect joint and a smoothly riding track, the splicing must be such as to make the joint as strong and as stiff as the solid rail; and also as flexible, so that it will return to position after the depression or deflection caused by

the loads, and thus carry the wave motion of the rail uniformly along the track. It should not, therefore, be more stiff or rigid than the rails to which it is applied. Very few joints have yet met these requirements, and the effect of the loading is to cause parts to become loose, and the rail ends to take a permanent set. Tamping the shoulder ties to a firm bearing will not compensate for weak deflecting rail ends or a weak splice.

At each rail joint, when under load, there are two beams fixed at one end and loaded at the other, each carrying half the load. The deflection of these two beams is nearly ten times as great as that of the rail carrying the same total load at the middle and considered as a beam. The strength of the rail itself counts for little at the joints, and does not suffice to distribute the load over several adjacent ties, as it does at the middle of the rail. The joint ties therefore have to take practically the whole impact of the load, besides being subjected to a rocking or pumping motion. It is for this reason that these ties go down more than the others. The great wear of the rails at the joint is caused by the jumping of the wheels over the deflected rail ends, and not over the expansion spacing between the rails. This wear is greater just beyond the joint, in the direction of traffic, and on single track a greater depression of the rail surface may be found on each side of the joint than at the joint itself. Fig. 41 shows a rail joint plotted

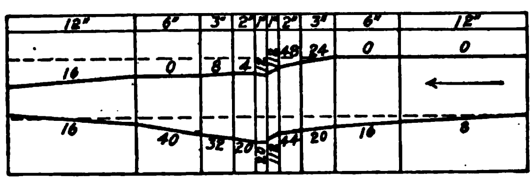


Fig. 41.—Diagram of Rail-Joint Deflections.

to an exaggerated scale for 2 ft. of each rail end. The upper line is for 80-lb. rails on gravel ballast, after 6 months' service; the lower line is for older and lighter track. The end of the receiving rail tends to be permanently depressed, having a flatter up-grade to the normal level than the leaving rail. Investigation and experiment have shown that the wheel, in spite of the spring and the vertical play, has not time to follow the deflection of the rail ends, but jumps the depression (especially as the curves are convex) and strikes the receiving rail a few inches from the end, causing the rail to wear or cut out at that point. With heavy rails and stiff joints the deflection (with consequent pounding, noise and wear) is minimized.

The drop at the gap left between the rail ends for expansion spacing will be almost imperceptible, for the versed sine of half the angle which has for its radius the radius of the wheel, and for its chord the width of the gap, is exceedingly small. With a 33-in. wheel and a ½-in. gap, the drop of the wheel and axle would be only 0.002-in.; and only 0.008-in. with a gap of 1 in. The drop at a gap of ¾-in. would be as follows: 30-in. wheel, 1/170-in.; 36 ins., 1/210-in.; 60 ins., 1/300-in.; 72 ins., 1/360-in. Experiments on the effect of the gap were made in Germany in 1892. On a sidetrack in good condition, notches 0.12 in. deep and 0.6 to 1.2 ins. wide were cut in the rail heads at points directly over the ties, where the rails could not deflect. Trial runs were made with a locomotive and inspection car, and the observers on the engine experienced noticeable shocks only in passing over the widest notches. Observers along the

track could scarcely distinguish the special noise produced by passing wheels, and increase of speed seemed rather to diminish the noise and magnitude of the shocks. On the other hand, experiments of the same kind made on the Michigan Central Ry. showed considerable wear at the notches.

The investigation of the merits of trial joints is a difficult matter, as in many cases they are put on with new rails or when the track is surfaced, and are assembled with special care. Any good results are then attributed to the efficiency of the joint, when they may be due to the improved track and the greater care in putting up the joints. A good angle-bar joint, put up with equal care and under the same conditions, would perhaps show even better results than the experimental devices. In many special forms of joint insufficient or no provision is made against upward deflection of the rail ends caused by the application of the wheel loads between the first and second ties (as shown by the Dudley dynagraph records, Chapters 5 and 21). This is followed by the better known downward deflection while the wheel is passing over the joint, and a second upward deflection after the wheel has passed the first tie beyond the joint. The standard angle bar in common use provides an extra thickness of metal on the upper edge as the practical outcome of experience, but the necessity for this appears to be overlooked in many special designs. The series of deflections above noted may be provided for to some extent by thorough tamping of the ties next to the joint ties.

Miter Joints.—The idea that the gap for the expansion spacing caused the shock led to experiments with miter or bevel joints as early as 1816 and 1824. In 1867, R. H. Sayre, Chief Engineer of the Lehigh Valley Ry., began experiments with rails cut at angles of 45° or 60°. This practice was followed from about 1869 to 1895, when it was finally abandoned, as many of the rails broke near the ends. The miter joint is now obsolete, except for use at drawbridge connections. It is hardly possible that the miter cutting of the rails caused any appreciable benefit, as it does not in any way affect the yielding of the rail ends, which causes the shock.

Scarf Joint.—This old plan has been revived abroad, the rail ends being halved or scarfed, placed side by side and bolted together. As used on the Prussian State Rys., the rails are scarfed for 8½ ins., and have 26-in. splice bars with four bolts spaced 5, 4 and 5 ins., c. to c. The two middle bolts pass through both rails and both bars. In the ordinary form, the strength of the joint is diminished by the thin web, but Mr. Vietor, of Germany, has designed a rail with the head not set central over the web, so that only the head need be planed away at the scarf, leaving both webs of full section. If this joint was put up like a riveted connection, or with tightly fitted bolts, it would be very stiff, but as the bolt holes must be large enough to admit of expansion, it is helped only by the friction of the webs, which depends upon the tightness of the bolts.

Continuous Rails.—The connecting up of long stretches of rails without the usual allowance for expansion and contraction movement at each joint has been referred to in the chapter on "Rails," while particulars of eliminating joints by welding the rails together are given in the chapter on "Electric Railways."

Splice Joint.—The flat splice bar or fish plate was invented in this country in 1830 by R. L. Stevens, for the Camden & Amboy Ry., and it was reinvented in England in 1847 by Mr. W. Bridges Adams. With the early pear-shaped T-rail the deflection of the rail ends under load tended to force the plates apart and loosen the joint. With the modification of the rail section to practically its

present form, with a high web and flat fishing angles, the joint became more practicable, and began to come into general use about 1855. This type of joint is now practically the standard throughout the world. It consists of two plates or bars, bearing against the under side of the rail head and the top of the rail base, and held together by bolts passing through the bars and the webs of the two rails. In order to increase the strength, the angle bar was devised (first rolled about 1868 or 1870), having a vertical web like the fish plate and an inclined flange extending over the rail base. This flange adds to the lateral stiffness of the joint and keeps the track in better alinement. In this country the angle-bar joint will probably continue to be the standard for the lighter track, but for first-class heavy track it is often supplemented by a base support to the rails, as noted below.

In some of the older joints, the outside bars extended along the side of the rail head, but this practice has been abandoned. The bars should be so designed and proportioned as to make the joint as strong and stiff as the body of the rail, but many joints are defective in stiffness to resist slight deflections. The bars are usually of uniform section throughout, but sometimes have the thickness of the web increased at the middle by tapering from the ends or by offsets. The flange sometimes extends only about ½-in. beyond the rail base, or barely enough to give a hold for the slot spikes, as in B, Fig. 42; in such case, these

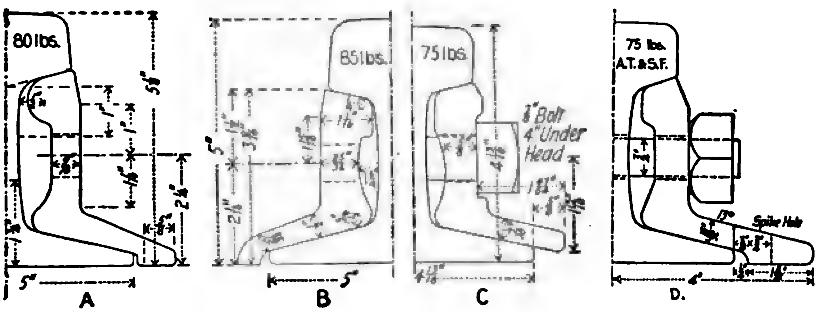


Fig. 42.—Sections of Splice Bars.

spikes may be crowded out of position by a creeping track. It is better to have wide flanges with deep slots for the spikes, and some roads have them wide enough for spike holes instead of slots, the spikes then resisting motion in every direction and the gage being more permanently maintained. The base of the flange is usually brought down level with the bottom of the rail, so as to take a bearing on the tie, as in Figs. 30, 35 and 42. Many roads, however, keep the flange clear of the tie, as in Fig. 42, C. The sections of splice bars vary very greatly, as shown in the illustrations, but one of the best is the Sayre section, shown in Fig. 30. The heavy top chord makes an exceptionally stiff bar, with wide bearing surface for the rail head. Fig. 42, A, shows the Dudley design of bar of high-carbon steel for the 80-lb. rails of the New York Central Ry. The thick, narrow-flanged bar of the Pennsylvania Ry. is shown at B, while C is the bar of the Chicago, Burlington & Quincy Ry.; the latter is grooved to hold the square bolt heads. At D is the heavily flanged bar of the Atchison, Topeka & Santa Fé Ry., having spike holes.

Splice bars are commonly made of steel which is far too soft for the purpose, having only about 0.10 to 0.15% carbon, or rarely 0.25%. Much better results

would be obtained with steel having from 0.30 to 0.40% carbon. The New York Central Ry. specifies from 0.25 to 0.30% carbon for bars not exceeding $\frac{9}{16}$-in. in thickness, and from 0.1 to 0.12% for bars over $\frac{9}{16}$-in.; the phosphorus not to exceed 0.06 and 0.05% respectively, while the manganese is from 1 to 1.3% in both cases. The Canadian Pacific Ry. requires bars of the same steel as the rails, 0.5 to 0.65% carbon. This practice is very general on foreign railways, but if the bars have slightly less carbon than the rails they will not cut the latter. In many cases a desire for increased strength is met by simply increasing the thickness of the web, coupled sometimes with an increase in the vertical thickness of the flange at its junction with the web. In the Dudley angle-bar section, already mentioned, the metal is distributed with a special view to stiffness, the web being even thinner than usual, but the steel has 0.40% carbon, and is hard and tough to resist wear. The section is stiff, but has sufficient elasticity to make it give long service before taking a permanent set, and the web is thin enough to stand clean punching, without distortion or warping. The steel is required to have an ultimate tensile strength of from 52,000 to 62,000 lbs. per sq. in.; elastic limit not less than half the ultimate strength; elongation, 25% in 8 ins.; and it must bend 180° flat on itself without fractures on the outside of the bent portion. The Illinois Central Ry. specifies the same requirements (but with 54,000 to 64,000 lbs.) for steel having a maximum of 0.15% carbon, 0.10% phosphorus, and 0.4 to 0.6% manganese. The Michigan Central Ry. has used splice bars of open-hearth steel having 0.65 to 0.70% carbon and 0.05% phosphorus. Under shop test they would stand a deflection of $\frac{1}{4}$-in. without permanent set. They have been very satisfactory in service on new rails, but will not hold up well on joints that have already deflected, which in fact few joint devices will do.

One of the bars usually has oval (or square or kite-shaped) holes to fit a neck of corresponding shape on the bolt, thus preventing it from turning as the nut is screwed up. The other bar has round holes, which should be of such size as to require a smart tap on the bolt to send it home. The present tendency is to punch both bars with alternate oval and round holes, alternate bolts being reversed. If the bolts have L-heads bearing on the flange of the bar, or square or T heads used with grooved bars (as at C, Fig. 42), both bars may be punched or drilled alike. The holes in the rails are large enough to allow of contraction and expansion. On the Memphis bridge and its approaches, for a total distance of about three miles, the joints originally had $\frac{7}{8}$-in. machine bolts with a driving fit in the holes of the splice bars, the holes in the rails being $\frac{1}{4}$-in. larger. In this way the two bars become practically one member, and good results were given until the splice bars began to wear, when it was almost impossible to tighten up the bolts. The arrangement has now been replaced with ordinary necked bolts and splice bars with oval holes.

The holes are usually punched, but drilling would be better, and holes made in rails already laid are drilled. The New York Central Ry. has a machine driven by steam and mounted on a car which will drill four holes at once. It is almost impossible to prevent thick bars from getting out of true if punched, and they should be straightened, as otherwise they will materially impair the efficiency of the joint. When splice bars are once notched or bent, the joint deteriorates rapidly, as it is almost impossible to restore the bars to proper line, though a straightening press has been used. To take up the wear at the top of the bar, under the rail ends (which wear at once reduces the efficiency of the

joint), a thin renewable bearing piece or liner may be set between the rail head and the bar, while some English railways use an iron washer at this point. It is obviously not economy to keep in service bent, worn, or crooked bars, as they lead to wear on the rails and general injury to the track.

In foreign practice it is very common to use bars of Z-section, having two vertical webs; the lower webs project below the rail and sometimes have bolts through them so as to cause the flanges to grip the rail base. This form of bar has been introduced in this country, as in the Bonzano, Thomson (or "100%"), Duquesne and Churchill joints. The Bonzano joint, Fig. 43, has a pair of angle bars with flanges about 3 ins. wider than usual. The middle portion of the broad flange is pressed (while hot) to project about 2¾ ins. below the base of the rail, thus giving additional stiffness. The bars are not cut or notched for bending. The others mentioned are of the same type, but the flanges are narrow at the ends, without the triangular web connection formed in the Bonzano bars. In the "100%" and Duquesne joints, the flanges are inclined inward beneath the

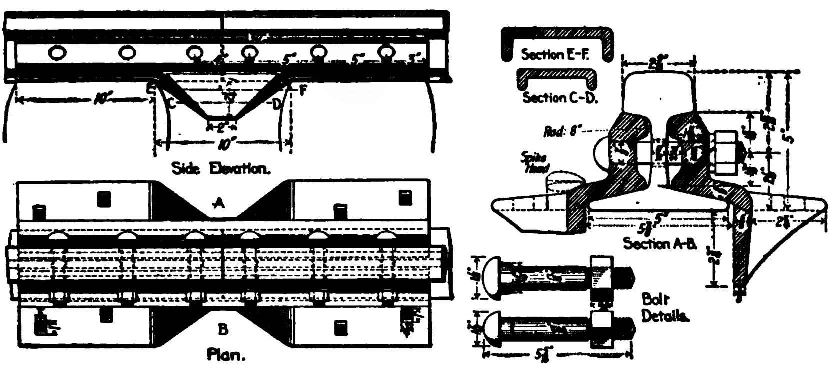


Fig. 43.—Bonzano Rail Joint; Pennsylvania Ry.

rail. Only in the Churchill joint are bolts used beneath the rail, as noted under "Bridge Joints." The 24-in. bars of the "100%" joint for 85-lb. and 100-lb. rails of the Am. Soc. C. E. sections weigh 38.94 and 37.62 lbs. each; they extend about 2¾ ins. below the bottom of the rail.

Breakage of Angle Bars.—The irregular manner in which splice bars fracture is due to the very varying conditions of load and support. The joint ties may be loose from the rails or loose from the ballast, and the transfer of the load from one rail to the other effects a reversion of strains in the angle bar at each wheel passage. Breaking of the angle bars from the bottom is often due to carelessness in raising track, the joints being raised too high before the centers or quarters are raised, instead of maintaining a proper surface in raising. With a wheel on each side of a supported joint, the tendency to is throw the joint up, the top of the bars being then in tension. With a suspended joint, the bars gradually get a deflection at the middle, and when the joint is raised, the tension strain is transferred from the bottom to the top of the bar. It has already been shown that the entering rail receives from each wheel a severe blow near the end, which tends to loosen and drive down the shoulder tie of a suspended joint, unless it is kept well tamped. If this tie is allowed to become low in the ballast, the angle bars get a tension strain along the top as each wheel passes. If the tie is tamped

up, and then allowed to get low again, the bars will eventually crack from the top. This may be prevented to some extent by lengthening the bars, though the ends of very long bars do but little effective work. Under normal conditions bars which fail should crack from the bottom rather than from the top. (See "Other Joint Devices.") Broken angle bars should be replaced at once, and the track examined to ascertain the cause of the breakage.

Supported, Suspended, Bridge and Base Joints.—There are four general arrangements of joints: (1) Supported joints, with the rail ends resting on a joint tie; (2) Suspended joints, with the rail ends projecting beyond the shoulder ties and held only by the splice bars; (3) Bridge joints, in which the rail ends project beyond the shoulder ties but are carried by a bridge plate resting upon the ties; (4) Base joints, in which the bridge plate is replaced by a support under the rails which is bolted or clamped to them, but does not rest upon the ties. The supported joint proper is now used to a comparatively small extent. With heavy wheel loads the joint tie does not give sufficient support, and if tamped hard to prevent it from settling, it forms an anvil upon which the rail ends are battered. The wave motion is not carried along uniformly and the track is likely to be rough. A modification of this arrangement, however, is the three-tie joint, in which two shoulder ties are placed close to the joint tie, and the angle bars are made long enough to extend over the three ties. This has been adopted by some important roads, and is considered to give good results under fast and heavy traffic. On the New York Central Ry. the ties are 5 ins. apart in the clear, while on the Illinois Central Ry. they are 10 ins. apart, both with 36-in. bars. It has been claimed that if the three ties are close together they cannot be properly tamped and that consequently one of three conditions will obtain: (1) The middle tie will be the more lightly tamped, making a suspended joint with a long span between the shoulder ties; (2) The shoulder ties will be the more lightly tamped, making a long and weak supported joint; (3) The third tie, or

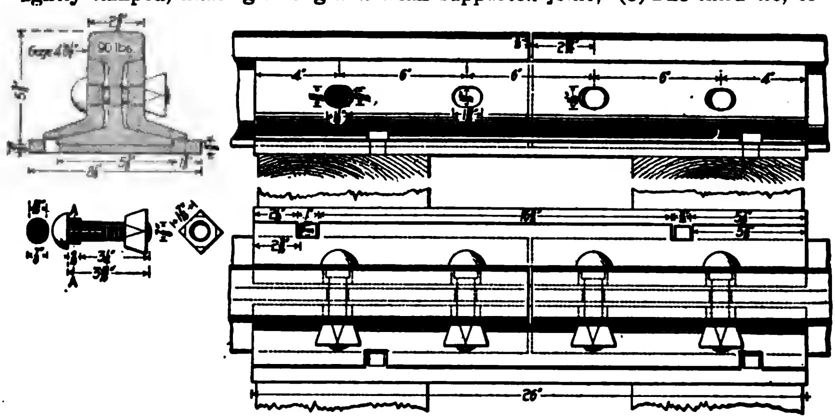
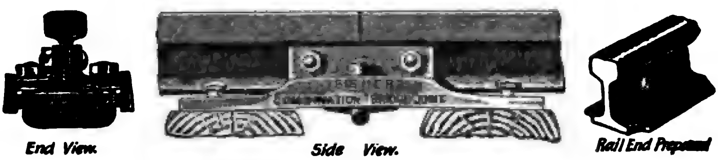


Fig. 44.—Rail Joint; Chicago & Northwestern Ry.

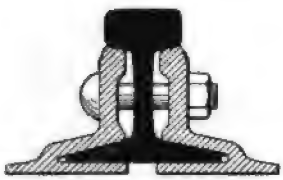
the shoulder tie of the entering rail, will be loosened by the jump of the wheels at the joint, and will thus cause the splice bars to be bent down, which with the reaction of the rail ends as the load is removed will cause them to crack from the top. Practical experience appears to show that these defects need not exist on well kept track. The suspended joint is the most generally used. It dis-

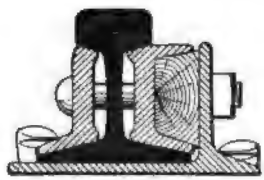
tributes the load over the two shoulder ties, and if the fastenings are properly designed it makes good provision for the deflection and wave motion. The general practice is to use suspended joints or bridge joints, with ties spaced 14 to 24 ins. c. to c. (or 6 to 10 ins. clear). Fig. 43 shows a suspended joint, and Fig. 44 shows the bridge joint of the Chicago & Northwestern Ry.

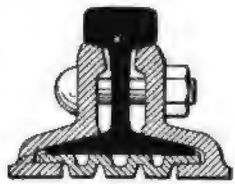
Bridge Joint.—This type is very extensively adopted, especially for main tracks with heavy traffic. The rail ends should be so attached to the bridge plate as to be incapable of independent movement. Several forms of bridge joints are shown in Fig. 45. The Fisher joint, now obsolete, had a slightly cambered bridge plate to which the rails were held by a transverse U-bolt with clamps resting on the rail base and fitting against ribs on the sides of the plate,

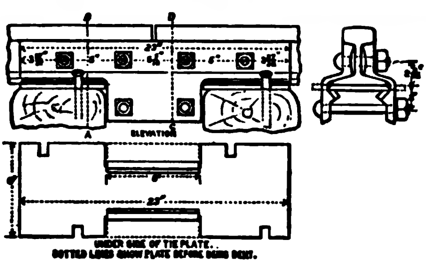


Fisher.

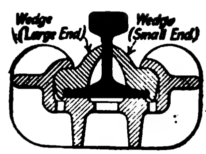

Continuous Joint.


Weber Joint.


Wolhaupter Joint.



Churchill.



Wedge Joint.

Fig. 45.—Rail Joints.

and also serving as splice bars. The Churchill joint, used on the Norfolk & Western Ry., has a bridge plate 23×8 ins., $\frac{9}{16}$-in. thick, with the sides bent down for 8 ins. at the middle to bear upon the ribs of the splice bars. These bars are 23 ins. long, with lower webs 8 ins. long, fitting the slots in the bridge plate. There are four ordinary splice bolts, but a special feature of the joint is the use of two $\frac{3}{4}$-in. bolts through the lower webs; these provide a means of forcing the bridge plate to a bearing against the base of the rails. The cost of maintenance was found to be very much less than where ordinary angle bars were used, while the joints were in better condition. The standard joint of the Chicago & Northwestern Ry., Fig. 44, has a grooved bridge plate 24 ins.

long, but the rails are not bolted to it. That of the Chicago, Rock Island & Pacific Ry. is similar, but the base plate is a channel $8 \times 1\frac{1}{2}$ ins., $\frac{1}{2}$-in. thick (1-in. flange); there are two flat grooves lengthwise of the rail. In the bridge joint introduced by Mr. Delano on the Chicago, Burlington & Quincy Ry., in 1890, 12-in. angle bars were secured by two bolts to the rail and two bolts to the bridge plate, though four bolts through the rail would have been better.

The Continuous joint has two angle bars with flanges fitting under the rail base. The Weber joint has an L-shaped bridge plate, the web of which is on the outer side of the rail, with a channel splice bar and wooden filler between it and the web of the rail. A fish plate or angle bar is used on the inner side of the rail. The Wolhaupter joint has a bridge plate with longitudinal corrugations, while the outer edge is clear of the ties and has on the upper side a rib or shoulder to fit the edge of the rail base. On the inside is a splice bar having the middle part of its flange widened and extended down to engage with a long slot in the edge of the bridge plate. On the outer side is a splice bar with a bottom flange filling under the edge of the bridge plate. These three patterns are very extensively used. The Atlas joint has malleable iron splice bars which extend under the rails and are grooved so as to receive and wedge upon the rail base, as in the Continuous joint. The bars are stiffened by ribs and may have projecting flanges to give an increased bearing on the ties; two bolts pass through lugs under the rails. In the Abbot joint, the bridge plate has stiffening flanges formed at the middle of each side, as in the deep splice bars of the Bonzano joint.

Base Joint.—A joint of this type was designed by Mr. Torrey, while Chief Engineer of the Michigan Central Ry. Under the rails was an inverted piece of rail (or crop end) 10 or 11 ins. long, slightly cambered so that its ends were $\frac{1}{16}$-in. clear below the base of the track rails. This was secured by three deep transverse U-bolts, whose legs passed through the wide flanges of four-bolt angle bars. The flanges did not touch the ties. Joints of this type, with pieces of I-beams or inverted rails riveted or bolted to the rails, are largely used in street-railway track.

Other Joint Devices.—An early form of joint which has been revived in Germany has bolted outside of the rails a special piece of rail resting on the shoulder ties and having its head level with and in contact with that of the track rails, so as to take the load off the latter. In the Barschall joint of this type, which has been tried on the Pennsylvania Lines, this auxiliary rail is about 20 ins. long, with its top level with the top of the track rail for 7 to 10 ins., and then inclined to the ends. The middle of the head must not be more than $\frac{7}{8}$-in. wide, so as to clear the false flanges of worn wheels. A splice bar is used on the opposite side, and a filler between the webs supports the heads of the main and carrier rails. Rail joints with wedge fastenings instead of bolts have been designed, but used only experimentally. The advantages claimed are the elimination of bolts and nuts, and the maintenance of a permanently tight joint. The general principle is that the rail ends lie within a heavy base plate of channel section (sometimes with sides sloping inwards) and are secured by long taper wedges. In a French joint of this type (Fig. 45) the base plate is a heavily ribbed steel casting, having on each side a vertical flange with an inside rib at the top. The wedges are of such shape as to bear upon the web and the top and edge of the rail base; also against the side and rib of the base plate. A wedge fastening used with steel ties is shown in Fig. 28. As the rail ends should rise and fall together, a hinge

joint would be ideal in some respects. In a five-bolt hinge joint used on the Indian Midland Ry., the middle bolt passes through notches in the ends of the rail webs, but the lack of fit between the bolt and the rail, and the small bearing upon the bolt, prevent this arrangement from having its full theoretical value. Hinged and dovetailed joints with interlocking rail ends have been devised, but the expense of shaping the ends makes their use impracticable. The number of patented joints is legion, but of those which have been tried experimentally many have been found to be inferior to a good angle-bar joint.

Step Joints.—Where rails of different section meet, either on the main track or where sidings have lighter rails than the main line turnouts, the smaller one is often blocked up to the proper height and the splice bars are bent to fit both webs. Step joints are more satisfactory. The Atlas step joint has two heavy malleable-iron side bars, projecting below the rail and having grooves made to fit the rail bases, which they grip tightly. Bolts are put through and under the rails. The Continuous, Weber and other joints are also made in special forms for this purpose. Mr. Sandberg has introduced cast-steel "step" splice bars, while on the Chinese Imperial Rys. Mr. Kinder has used cast-steel rails 27 ins. long, having half the length conforming to a 60-lb. and the other half to an 85-lb. section. These are secured to the rails by the ordinary splice bars. A somewhat similar joint was devised by Mr. W. G. Curtis of the Southern Pacific Ry., but made from a piece of the heavier rail, 7½ to 30 ft. long. The outer side of the head was planed away gradually to fit the smaller rail, and the bottom forged to conform to this rail for about 12 ins., beyond which the change to the heavier section was made in 15 ins. A reinforcing plate riveted to each side of the rail butted against the splice bars of the lighter rail.

Insulated and Bonded Joints.—Where rails are utilized to carry electric circuits for automatic block signals, etc., they must be electrically bonded at the joints to give free passage for the current. This is usually done by wires attached to copper studs or plugs set in holes in the web or base of the rail. The wires are laid inside or outside the splice bars. At the ends of the block sections insulated joints must be used to prevent the passage of the current. A ¼-in. strip of treated wood or vulcanized fiber is placed between the rail ends, and the rails are insulated from the splice bars and bolts. Many of the joints already described are adapted to this purpose. In the Bonzano joint, a fiber plate is laid under the rail ends, and on each side is a similar plate laid against the web and extending between the top and bottom contact surfaces of the rails and splice bars; fiber bushings and washers insulate the bolts. To prevent wear of the fiber base plate, a steel plate is laid under it and bolted to the splice-bar flanges. In the Weber joint, an L-shaped sheet of fiber is laid on the bridge plate and heavy wooden splice bars are used, one of which fills the space between the rail web and leg of bridge plate. The "100%" joint has a triangular wooden block placed under the rail and between the inwardly inclined flanges of the deep splice bars, being secured by two bolts through these flanges. The Mock joint has an outside carrier rail, with a strip of insulating material between it and the heads of the track rails. The Neafie joint, used on the Delaware, Lackawanna & Western Ry., has a long channel-shaped plate, and a ½-in. layer of wood under the end of the leaving rail (thus giving the receiving rail a support on the plate); wooden splice bars 3×4 ins., 3 ft. long, fit tightly between the rails and the sides of the channel. Besides the joint bolts, two vertical bolts on each side pass down through the bars and plate, the nuts under the plate being kept from slacking

loose by split keys driven through slots in the bolts. The Pittsburg joint has angle splice bars with the flange on top, and outside of these are drop-forged splice bars, a channel-shaped strip of fiber lying against the inner bar and base of rail. The outer bars are of channel section, thicker at the middle than at the ends, and made solid at the bolt holes so as to require long bolts. Each bolt has a flanged bushing on each end, with a metal washer between the flange and the head or nut.

Expansion Joints.—With continuous rails and where creeping cannot be checked, expansion joints must be provided at intervals, and these are usually made with switch points. On long-span steel bridges some special joint must be used to allow for the movement at the expansion joint in the structure. These usually have the rails lapped or scarfed, so as to maintain a continuous rail while allowing for sufficient longitudinal motion in the adjacent rails. Fig. 46 shows

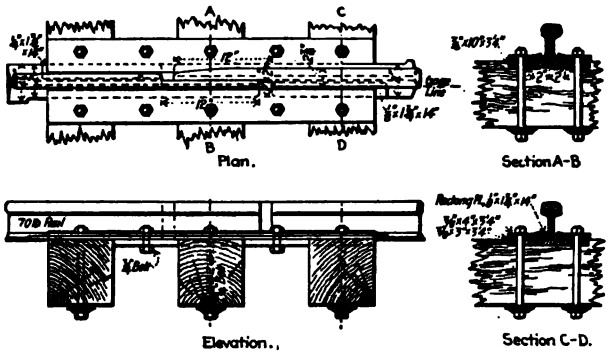


Fig. 46.—Expansion Rail Joint; Poughkeepsie Bridge.

the form used on the Poughkeepsie bridge, which provides for several inches of movement. A heavy base plate and upper packing plates form a trough in which the rail ends slide, the rails being "halved" for a length of 12 ins. Neither rail has its web cut. On the gage side of the rail the line is made perfect by planing off from the inside of the head an amount equal to the thickness of the web, the rail being slightly bent beyond the joint so as to permit this. The other rail is left of its original thickness. At the ends of the four anchor arms of the Thebes cantilever bridge, the rails do not lap, but have their ends 7 ins. apart. Wheels are carried across the gap by carrier or bridge rails laid against the outside of the track rails and bolted to one of them. The outside face of the rail head is planed away to a width of 25/32-in. for a length of 18 ins. on the fixed end, and 30 ins. on the expansion end. The carrier rail is a rectangular bar of tool steel, laid against the web and head; it is bolted to one and slides against the other, being controlled by cast-steel guides. A guard rail on the gage side gives a flangeway of 1¾ ins. and holds the wheels over so that they will take a full bearing on the carrier rail. (Engineering News, Aug. 22, 1907.) The expansion joint used on the Memphis bridge consists of two short switch rails which slide against each other. These rest on a steel plate which has a flange on the outside so that the two tapered rails cannot separate. This joint when closed is 3.4 ft. long, and provides for an expansion of about 1½ ft. There are three of these joints on the bridge. There is a total expansion and contraction movement of about 3 ft. across the entire bridge, but part of this is due to

the creeping of the rails. There is a considerable grade on the north approach, which tends to cause the creeping. The rails are not anchored on the bridge proper, but are anchored at intervals of 50 ft. on the approach by pieces spiked in such a manner as to brace against the angle bars. (See "Creeping of Rails.")

Drawbridge Joints.—At the ends of swing bridges, special joints must be provided in order to allow of the rails bridging the gap between the abutment and the end of the bridge. In some cases the end rails on the bridge are 10 or 15 ft. long, pivoted at the heel, and projecting about 1 ft. or 2 ft. so as to take a bearing on the abutment tie or sill. A trough or channel-shaped rest plate having flaring sides guides the rail into its proper position in alinement with the fixed rail. The joint of the pivoted and fixed rails may be mitered in a length of 6 to 8 ins. The joint may also be locked by wedges sliding longitudinally between the rail webs and the sides of the channel, thus making a substantial connection for high-speed traffic. When the bridge is to be opened, the ends of the pivoted rails are raised clear of the trough by mechanism operated from the bridge locking gear, and when the bridge is closed it should be necessary for this mechanism to pull the rails down into position before the signals can be released. Relying upon gravity to return the rails to position has caused serious accidents. As these rails cannot be spiked to the bridge ties they should move between guides which hold them laterally. With lift or bascule bridges, the rails need not be pivoted, but the meeting ends of the fixed and bridge rails may be cut vertically at an angle. Drawbridges should be so equipped with interlocking apparatus that the bridge locks cannot be released or rail-lifts raised until the signals on the approaches have been set at "stop," and so that these signals cannot be cleared until the rails and locks are restored to their normal position.

Broken and Even Joints.—The rails may be laid with joints opposite one another, or with the joints on one side opposite the middle of the rails on the other side. The latter is by far the most general practice for main track, both on tangents and curves, but even or square joints are sometimes used on tangents. Even joints are also used sometimes on new lines not fully ballasted, on account of the banks settling. Under such conditions and on light track where the joints settle, it is claimed that the track rides easier, has less lateral motion and can be maintained better. With broken joints, according to their opponents, the number of low places would be increased, and the weight of the train would be thrown against low joints, tending to throw the track out of line. On the other hand, even joints tend to form kinks in the track and generally result in greater wear of the rail ends. On many western roads, with comparatively light track, it is considered that broken joints make easier riding track, less liable to get out of line and less expensive to maintain. With broken joints, the hammering effect which tends to cause low joints is better distributed over the track (particularly when it is well ballasted), and there is less difficulty in keeping up the joints. The cars also ride more smoothly. Tracklaying takes more time with square joints than with broken joints, while with the latter the joints can run some distance ahead of the middle of the opposite rail (on curves) before it becomes necessary to cut a rail or insert a short rail. In fact, some roads using square joints on tangents use broken joints on curves. The prevailing opinions are strongly in favor of broken joints for all kinds of track, as they make a better running track, hold the surface and line better, and require less maintenance work. This latter point is important on a road with light track and a limited track force.

Length of Bars and Spacing of Bolts.—There is very little uniformity in these details, but there is a decided tendency towards the use of short bars and closely spaced bolts, as may be seen by comparing the old and modern joints given in Table No. 9. The length of bars is from 20 ins. with four bolts, to 48 ins. with six bolts. Both extremes are now obsolete. The logic of the very long bars is hard to see, especially where the bolt holes are several inches from the ends, as the metal beyond these holes does little service. The bolt-hole spacing formerly ranged as high as 12 ins., but 9 ins. is now about the maximum, and even that is exceptional, the more common practice being to space the bolts from 4 to 6 ins. c. to c. Very wide spacing is objectionable, and it is advisable to get the center bolts as near as possible to the ends of the rails while still leaving metal enough to insure against cracking or fracture of the rails. Bars 24 and 26 ins. long, with four bolts spaced from 4 to 6 ins. c. to c., represent the general practice; where six bolts are used, the bars are generally from 28 to 38 ins. long. Table No. 9 shows the arrangement of a number of joints, and further details will be found in the appendix.

TABLE NO. 9.—RAIL JOINTS.

Railways.	No. of Bolts.	Length of Bar.	Bolt spacing, c. to c. Middle.	Bolt spacing, c. to c. Intermed.	Bolt spacing, c. to c. End.	Type of Joint.	Weight of Rail.
		ins.	ins.	ins.	ins.		lbs.
Wabash	4	24	5	....	5	Suspended	80
Boston & Maine	4	24	6	....	6	Bridge	85
Cincinnati Southern	4	24	4	....	7	Bridge	85
Chicago & Northwestern	4	26	6	....	6	Bridge	90
Buffalo, Roch. & Pitts.	4	26	7	....	7	Suspended	80
Southern Pacific	4	27	5½	....	5½	Suspended	90
Nash., Chatt. & St. Louis.	6	26	4	4	5	Suspended	80
Cleve., Cin., Chi & St. Louis.	6	30	4	5	6	Suspended	80
Pennsylvania Lines	6	33	5	5	6	Suspended	..
New York Central	6	36	5.6	5.6	5.6	3-tie	100
Cleve., Cin., Chi. & St. Louis	6	38	6	6	7	3-tie	90
Michigan Central	6	44	6	6	9	3-tie	80
Sav., Fla. & West. (old)	6	48	6	12	6	3-tie	75
Lake Shore & Mich. So. (old)	6	48	6	6	11	Supported	70
Erie (old)	6	40	8	6	7	Suspended	80
Concord & Montreal (old)	4	36	6	....	6	Suspended	72
Boston & Albany (old)	4	20	4½	....	4½	Supported	95

Bolts and Nuts.—Track bolts are usually made of mild steel, and are ¾- or ⅞-in. diameter, a very few roads having them as large as 1-in. for heavy rails, while ⅞-in. and 1-in. bolts are used for frogs. They are 3½ to 4¾ ins. long under the head, according to the style of joint, but should not project more than ¼-in. beyond the nut. They are put up in kegs of about 200 lbs. A keg contains about 240 bolts $\frac{3}{4} \times 3\frac{1}{2}$ ins., with nuts; 208 bolts $\frac{3}{4} \times 3\frac{3}{4}$ ins., with 1½-in. nuts; or 195 bolts $\frac{3}{4} \times 4\frac{1}{4}$ ins., with 1½-in. nuts. The bolts should be straight and smooth, with well-cut threads, and the threaded portion should be as short as possible, so as to give the body of the bolt a full bearing in the splice bar. The threads should be of U. S. standard, so made on both bolt and nut that the nut can be screwed on by hand only for the first three or four threads, after which it must be turned by the wrench, the fit not being so tight as to burst the nut or distort the threads in screwing up with an ordinary track wrench. The Harvey grip-thread bolt, Fig. 47, has the thread spun up on the body by a cold-rolling process, the threads rising $\frac{1}{16}$-in. above the body of the bolt, while in the ordinary bolt the thread is cut out of the body and so reduces the thickness at the root. The Wrenshall oval bolts, used at one time on the Northern Pacific Ry., were $\frac{7}{8} \times \frac{11}{16}$-in.

The bolt has usually an oval or square neck under the head, fitting into a hole of corresponding shape in the splice bar, in order to prevent the bolt from turning while the nut is being screwed on or off. The length of the neck should be equal to the thickness of the splice bar. The bolts usually have cup heads, but the heads are often too small and too thin at the edge, so that the wear in the edge is likely to reduce the bearing surface, especially as the contact surfaces are often too rough for a good bearing. A few roads use a square head and a grooved splice bar, both bars being punched alike (Fig. 42). The New York Central Ry. specifies that the bolts must be of soft steel, $\frac{3}{4}$-in. test pieces showing 58,000 to 65,000 lbs. ultimate tensile strength, an elastic limit at least 50% of the tensile strength, and an elongation of at least 25% in 8 ins. The bolt must have a tensile strength of at least 50,000 lbs., and an elongation of 30% or 2 ins.; it must be bent and hammered down upon itself without any sign of fracture in the body and with only slight cracks at the root of the thread.

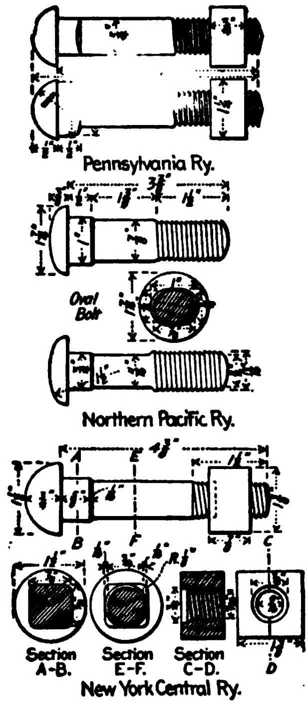


Fig. 47.—Track Bolts.

The nuts should be well formed, with true and clean-cut threads, and should be thick enough to give a good bearing, as thin nuts result in loose nuts and damaged threads. Both square and hexagonal nuts are used, the former being the more general. The corners are sometimes chamfered toward the inner face, in order to give a better hold for the wrench. The nut may be on the inside or outside of the rail, but many roads put them alternately on the inside and outside, so as not to have all the bolt necks on one side, and to prevent derailed wheels from breaking all the bolts of the joints.

Nut Locks and Lock Nuts.—A nut lock is usually placed between the nut and the bar, to prevent the nut from working loose. Lock nuts, however, render these unnecessary, and thus reduce the number of parts. Several devices of both kinds are shown in Fig. 48. The Harvey grip-thread bolt has a ratchet thread, undercut on the bearing side, or about 5° less than a right angle to the axis of the bolt. The nut has a similar thread, the bearing side of which is about 5° greater than a right angle to the axis of the nut. The thickness of face of thread and the depth between threads are increased towards the outer end of the nut by flattening the angle of the thread. When the nut is screwed hard against the splice bar, the thin sharp threads of the bolt are upset so as to fill the space of 10° between the threads of the bolt and the nut. The hole in the nut is enlarged at the bearing face, forming a chamber $\frac{1}{16}$-in. deep, thus insuring good threads on which to screw the nut in taking up any slack. The Oliver nut has the three outer threads of the ratchet form and cut at a slightly different angle from the others, thus setting up a tight grip on the bolt. The National elastic nut is made from a flat strip so shaped as to

form a scarf joint when bent into a ring and pressed into hexagon form. It is tapped slightly smaller than the bolt, so that when put on it is sprung slightly open and exerts a grip on the bolt. There is also a nut made from a spirally-coiled bar; the end coils are slightly open but are forced together as the nut is screwed against the splice bar. The Spring nut is drawn flat against thesplice bar by the bolt, the spring action of the wings then preventing it from slacking.

Most nut locks are in the form of spring washers (Fig. 48). Probably the most extensively used is the Verona, which is a steel split washer twisted

Fig. 48.—Nut Locks.

spirally to give about ¼-in. opening. Many modifications of this design have the metal twisted, jagged or pointed so as to cut into the splice bar, but the advantages of such practice are dubious. Some nut locks are made to fit a pair of bolts, like the Excelsior double nut lock. The spring action is not the only principle adopted. The Jones nut lock is a thin flexible plate, the edge of which comes against the rail head or splice bar, while one end is bent up against the nut when the latter is screwed home. The Stark nut lock has a keyway on the bolt and eight keyways in the nut, so that at each one-eighth turn of the nut a slot is formed to receive a split pin.

Examples of Rail Joints.—The Chicago & Northwestern Ry. has a four-bolt bridge joint (Fig. 44) with shoulder ties 9½ ins. apart in the clear. The bridge

plate is channel-shaped, 26 ins. long, $8\frac{1}{2}$ ins. wide, $\frac{3}{4}$-in. thick for $5\frac{1}{2}$ ins. (to fit a $5\frac{3}{8}$-in. rail base), and $\frac{3}{8}$-in. for a width of $1\frac{5}{16}$ ins. at the sides. The splice bars are 26 ins. long, with bolts 6 ins. c. to c. They are thin, and the flanges are clear of the bridge plate, projecting over it far enough for the spike slots to register with square holes in the plate. One bar has oval holes, $\frac{15}{16}\times1\frac{5}{16}$ ins., while the other has holes $1\frac{1}{16}$ ins. diameter. The Harvey bolts are $\frac{15}{16}$-in. diameter, $3\frac{15}{16}$ ins. long under the head, with a neck $\frac{15}{16}\times1\frac{1}{4}$ ins., $\frac{5}{16}$-in. long. The nut is $1\frac{7}{16}$ ins. square and 1 in. deep, with chamfered corners. The New York Central Ry. uses three-tie joints, with ties 5 ins. apart, and tie-plates on all ties. The splice bars are 3 ft. long, with six bolts 5.6 ins. c. to c., and each bar has alternate square holes (with rounded corners) and circular holes. For 100-lb. rails (with $1\frac{1}{16}$-in. round holes), the bars have holes $1\frac{1}{16}$ ins. square and 1 in. diameter; $\frac{7}{8}$-in. Harvey bolts with $1\frac{1}{16}$-in. square neck and $\frac{1}{8}$-in. corners. For 80-lb. rails (with 1-in. round holes) the bars have holes $\frac{15}{16}$-in. square and $\frac{7}{8}$-in. diametor; $\frac{3}{4}$-in. bolts with $\frac{3}{4}$-in. square neck. In both cases square nuts $\frac{7}{8}$-in. thick are used, $1\frac{1}{2}$ or $1\frac{3}{8}$ ins. square.

The Delaware, Lackawanna & Western Ry. uses 30-in. angle bars with six bolts; the two middle bolts are spaced $4\frac{1}{2}$ ins. and the others $4\frac{3}{4}$ ins. c. to c. The holes are $1\times1\frac{3}{16}$ ins. in both bars, and $1\frac{1}{8}$ ins. diameter in the rails. The bars are of the general section B in Fig. 42, but the narrow flanges are $\frac{1}{8}$-in. clear of the tie. Those for the 100-lb. rails, however, are of the Sayre type (Fig. 30) with flanges $\frac{3}{16}$-in. above the tie. The spike slots are $\frac{3}{4}$-in. wide, $\frac{7}{8}$-in. deep in the narrow and $1\frac{1}{16}$ ins. in the wide-flanged bars. The Harvey grip-thread bolts are used, $\frac{7}{8}$-in. at the body and $\frac{15}{16}$-in. over the threads (9 threads to the inch). They have oval necks $\frac{7}{8}\times1\frac{1}{2}$ ins., and button heads $1\frac{1}{2}$ ins. diameter and $\frac{11}{16}$-in. thick. The nuts are $1\frac{7}{16}$ ins. square (or over the faces for hexagon nuts) and $\frac{7}{8}$-in. deep. The nut locks are of the Verona tail pattern. The Baltimore & Ohio Ry. has four-bolt suspended joints for 100-lb. rails, with bolt holes $1\frac{1}{16}$ ins. and $1\frac{3}{16}$ ins. diameter for 33-ft. and 60-ft. rails. The 26-in. angle bars have holes alternately 1 in. diameter and $1\times1\frac{5}{16}$ ins. oval. They are $\frac{7}{8}$-in. thick, and have narrow flanges $\frac{1}{8}$-in. clear of the ties. The spike slots are $\frac{3}{4}$-in. wide, deep enough to bring the spike against the edge of the rail. The bolts are spaced 5, 6 and 5 ins. c. to c. They are $\frac{7}{8}$-in. Harvey bolts, $4\frac{3}{4}$ ins. long under the head, with the neck $\frac{5}{8}$-in. thick and tapering from $\frac{15}{16}\times1\frac{5}{16}$ ins. to $\frac{7}{8}\times1\frac{1}{4}$ ins. The nuts are $1\frac{7}{16}$ ins. square, $\frac{7}{8}$-in. thick; $\frac{1}{4}$-in. nut locks are used. Where six-bolt joints are used, the bars are 28 ins. long, with holes alternately $1\frac{1}{8}$ ins. and $1\frac{1}{8}\times1\frac{1}{2}$ ins. The end bolts are spaced $5\frac{1}{2}$ ins. and the others 4 ins. c. to c.; they are 1-in. bolts with hexagonal nuts $1\times1\frac{7}{8}$ ins. The Missouri Pacific Ry. uses suspended broken joints with 26-in. bars and four bolts spaced 5 ins. c. to c. The holes in the bars are alternately $1\frac{1}{16}$ ins. diameter and $1\frac{1}{16}\times1\frac{7}{16}$ ins.; the holes in the rails are $1\frac{1}{8}$ ins. diameter. The bolts are 1 in. diameter, with $1\frac{5}{8}$-in. square nuts 1 in. deep. The Verona nut lock with tail is used, the metal being $\frac{1}{4}\times\frac{3}{16}$-in. The shoulder ties are laid with their rear sides in line with the ends of the angle bars.

Track Material.

The quantity of track material for one mile of single track with 30-ft. rails (giving 352 joints) is given in Table No. 10. With rails 33 ft., 45 ft. and 60 ft. long, the number of rails per mile will be reduced to 320, 234.6 and 176 respectively. The weight of rail per yard divided by 7 and multiplied by 11 gives the weight in gross tons per mile of single track.

TABLE NO. 10.—QUANTITIES OF TRACK MATERIAL.

	No.
Rails, 30 ft. long	352
Ties, 16 per rail	2,816
Tie-plates (2 on each tie)	5,632
Splice bars	704
Joint bridge-plates	352
Track bolts (4-bolt joints)	1,408
Track bolts (6-bolt joints)	2,112
Nuts (4-bolt joints)	1,408
Nuts (6-bolt joints)	2,112
Nut locks (single) (4-bolt joints)	1,408
Nut locks (single) (6-bolt joints)	2,112
Spikes or screws, 4 per tie	11,264
Clips for screw spikes, 4 per tie	11,264

CHAPTER 7.—SWITCHES AND FROGS.

The switch is the device by which a train is diverted from one track to another. The turnout includes the switch, frog, lead rails, etc., forming the complete connection between the two tracks. The curves of main-line turnouts are usually of 6° to 8°; sharper for low speeds and easier for high speeds (see Table No. 11). The split switch (now almost universally used) was introduced in England as early as 1825. In this country the stub switch was at one time generally employed, but is now rarely used. The switch angle is that contained between the two positions of the rail in a stub switch, or between the switch and stock rails of a split switch. A switch is right handed or left handed, according as the turnout is to the right or left of a man standing on the main track and facing the turnout. Switch work is discussed in another chapter.

Stub Switch.—This consists of two movable rails, having the heels (or ends furthest from the turnout) spliced to the track rails, while the free ends slide so as to coincide with the stub or fixed rails of one or other track, as shown in Fig. 49. The rails are connected by tie-rods, so as to act together, and the throw

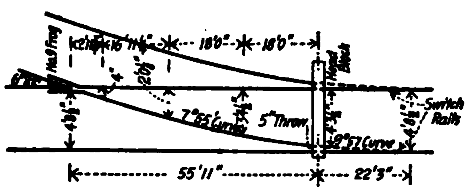


Fig. 49.—Stub Switch.

or movement of the free ends is about 4 or 5 ins. They are usually 30 ft. long, and in order that they may be sprung to a curve they are spiked to the ties for a certain distance beyond the heel (about 5 ft. for a 7½° turnout curve or 12 ft. for a 15° curve). If hinged only by the splice joints at the heel, the rails will remain straight when set for the turnout, thus forming an angle or kink at the heel and toe. The toe of each rail rests on a head plate or head chair (Fig. 50) about 10×16 ins. This has lugs to limit the throw and is also formed to hold the ends of the stub or fixed rails and keep them from creeping. These rails should also be bolted together with a filler block between the webs. The head chairs are spiked to a long tie or head block about 8×12 ins., 12 to 16 ft. long, the end of which carries the switchstand. This form of switch is neither safe, efficient, nor economical, even when fitted with castings which move with the rails and are designed to carry wheels trailing on the wrong track, which would otherwise drop off the ends of the stub rails onto the ties. The space between

the ends of the switch and stub rail is often as great as 2 ins., causing severe wear to wheels and switch. On the other hand, the switch rails may expand in hot weather so as to be jammed in the head chair, though this may be avoided to some extent by beveling and lapping the rail ends for about 12 ins., as at drawbridge connections. In this case, the head chair has no end stops. Under heavy traffic it is difficult to keep stub switches in proper condition. In yards having such switches, a large proportion of the track work is in maintaining and repairing the switches, and replacing switch rods and connections damaged by derailments.

Split Switch.—This consists of two point or switch rails (straight or curved to fit the curve of the turnout), planed tapering to a vertical edge, so that the ends will fit close against the main or stock rails. The heels of the switch rails are towards the diverging tracks, which is the reverse position from that of the stub switch rails. The two outer rails of these tracks are continuous, the outer rail of the main track continuing unbroken, while the inner rail follows the curve of the turnout. The switch rails are between these stock rails, with a space of about 5 to 6½ ins. between the gage lines at the heel, or a clearance of from

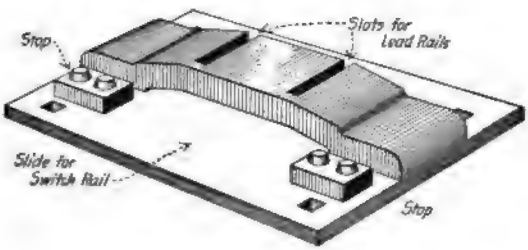


Fig. 50.—Head Chair for Stub Switch.

2½ to 3½ ins. (preferably 3 ins.) between the rail heads. The throw of the point ends is from 3½ to 5½ ins., so that when one switch rail is home against its stock rail the other is from 3½ to 5½ ins. from the other stock rail. About 12 or 16 ins. ahead of the point, the stock rail on the turnout side is given a decided kink or bend by means of a rail bender, so that when set for the main line, the gage sides of the stock and switch rails will be in exact alinement. This is shown at A in Fig. 67.

The switch rails are connected by three to six tie rods, though many roads use only one, placed close to the point. The larger number may be used with long switch rails at high-speed switches. The rods are either round or flat, with jaws on the ends to receive the angle clamps bolted to the webs of the rails, and the end switch rod or head rod is generally adjustable, so that wear or slack can be taken up to keep the gage true. The adjustment is made by having the rod in two parts, connected by turnbuckles or clevises or by special forms of attachment. With turnbuckles, each end of the rod has a right-hand thread. The gage is not affected by turning the turnbuckle (as by persons tampering with the switch), but the rod must first be disconnected and the bolts removed from the end fastenings. Some roads, however, prefer to use rigid or non-adjustable rods. The rods should lie between ties spaced about 4 ins. apart, to protect them from injury in case of derailment. The insulated head rod used at interlocking plants by the Delaware, Lackawanna & Western Ry. is in two parts,

each being a bar $\frac{3}{4} \times 2\frac{1}{2}$ ins., twisted at the inner end so as to be on edge. The ends (not in contact) are spliced by flat plates and six bolts, fiber sleeves being fitted to the bolts, and fiber plates $\frac{1}{4} \times 2\frac{1}{2}$ ins. between the bars and splice plates. To the head rod is attached the connecting rod from the switchstand, and the ends of the head rod pass under the rails to prevent the ends of the switch rails from rising. The stock (or main) and switch rails rest on flat steel plates on each tie; these prevent the rails from cutting the ties (with consequent tilting of rails and widening of gage), and form slide plates for the switch rails. Each plate may have a lug to hold the heel of a rail brace on the outside. On the tie at the point of the switch should be a plate extending along the tie under all four rails, so as to assist in maintaining the gage; it should have shoulders to fit the outside edges of the stock rails, and lugs to fit the heels of the rail braces.

The standard split switch for 85-lb. rails on the Norfolk & Western Ry. is shown in Fig. 51. The switch rails are 15 ft. long, connected by two rigid tie

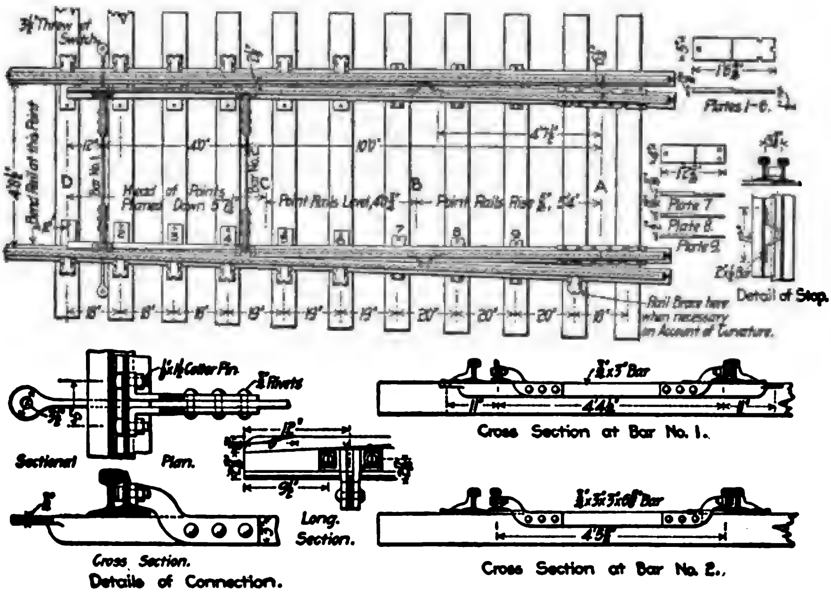


Fig. 51.—Standard Split Switch; Norfolk & Western Ry.

bars, $\frac{3}{4} \times 3$ ins., set on edge, having riveted jaws bolted to the rails. Formerly, 18-ft. switch rails were used, with five rods. The throw of the switch is $3\frac{1}{2}$ ins., and the width over gage lines at the heel is $6\frac{1}{4}$ ins. Rail braces are put at the heel and on six ties at the point. About 5 ft. from the heel is a stop lug, riveted to the switch rail, so that when the rail is home this will bear against the web of the stock rail, and prevent the pressure of the wheel flanges from bending the rail. There are 18 slide plates; Nos. 1 to 6 are $18\frac{9}{16} \times 5$ ins., $\frac{1}{2}$-in. thick for $9\frac{13}{16}$ ins., and then $\frac{11}{16}$-in. thick; the other three are $14\frac{9}{16} \times 4$ ins., with the raised part $7\frac{3}{4}$ ins. long, and thicknesses as follows: No. 7, $\frac{5}{8}$-in. and $\frac{11}{16}$-in.; No. 8, $\frac{3}{8}$- and 19/32-in.; No. 9, $\frac{3}{8}$- and $\frac{1}{2}$-in. All have $\frac{3}{4}$-in. spike holes. The thicker part is to raise the switch rail slightly above the stock rail as noted below. The switch rails are planed to fit closely against the stock rails for 5 ft. $7\frac{1}{4}$ ins. from the point, and the inner edge is planed off for 7 ft. from the point.

The length of switch rails in main track is usually 15 ft. for ordinary turnouts, and should not be less than this. The Philadelphia & Reading Ry. uses 15 ft. for frogs of Nos. 6 to 8, 20 ft. for Nos. 9 to 12, and 30 ft. for Nos. 12 to 20. On the Pennsylvania Lines, 18 ft. is standard, and 30 ft. for a No. 20 frog. Other roads use 30-ft. switch rails at connections of double-track to single-track or four-track, where trains run at high speed and the frogs are of Nos. 20 to 24. Such long switch rails may have two or three stops to support them against the webs of the stock rails. If a 30-ft. rail is cut in two pieces 15 ft. 1 in. and 14 ft. 11 ins. long, and these are placed in the curved and straight track respectively, the heels will be exactly opposite, so that the joint ties at the heel will be square across the track. For switches leading from the outside of curves on main line, the switch rail on the inner side of the main track should have its point about 24 ins. in advance of the other, with a guard rail opposite, as noted below. Switch rails 10 and 12 ft. long are used in yards and unimportant tracks.

To secure the long feather-edge lying against the stock rail, it is necessary to plane off a portion of the head and base of the switch rail. This long thin end is a weak point, having little strength to resist blows or bending. For this reason the top at the extreme point is often planed off so that when home against the stock rail it will be below the wheel flanges. The end of the switch rail is left about ⅛-in. thick, and the top is planed down on a slope for 6 to 15 ins., giving a drop of ¾- or ⅞-in. below the top of the stock rail, the corner of the switch rail being rounded off vertically. This is to prevent wheel flanges from striking the point. These rails are now very generally reinforced by flat bars on both sides of the web, or by a T-bar on the gage side. Manganese steel switch rails (which are cast to shape) have been tried; but there is liability of these thin hard rails cutting the wheels, especially where the trucks do not swing easily. The metal is better adapted to the heavy switch rails of special section used in the Wharton and MacPherson switches. The German railways use (instead of the long thin rail) a switch rail of rectangular section, but with a bottom flange. It is 17½ ft. long, planed for about 11 ft., and having on top a tapered rib to fit against the head of the stock rail. Three forms of these heavy switch rails are shown in Fig. 52; these are used by the State railways of Prussia,

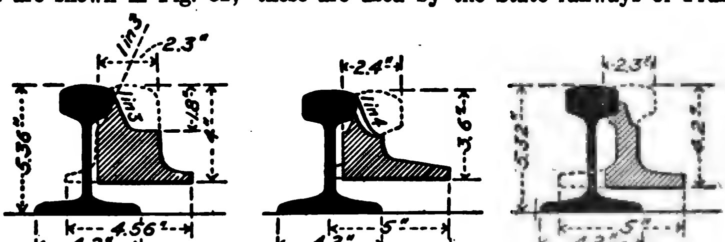


Fig. 52.—Switch Rails of German Railways.

Baden and Bavaria, respectively. On the Netherlands State Railways each switch rail has a vertical pivot fitting in a casting bolted to the tie at the heel (no splice being used), and the switch and stock rails rest on a steel plate 19 ft. long and 13 ins. wide. Switches with pivoted rails moving vertically have been tried, but the diversity of distance back to back of wheels is likely to cause derailments.

The switch rail is usually slightly higher than the stock rail, so as to carry the false flanges of worn wheels over the latter and prevent them from wedging between the rails. In the Norfolk & Western Ry. switch, the head of the rail

rises $\frac{5}{16}$-in. in 5 ft. 4 ins. from the heel, and is then level for 4 ft., beyond which it is planed down to the point, 5 ft. $7\frac{1}{4}$ ins. In other designs, the heads of the switch and stock rails are level at 12 or 15 ins. from the point, but then the former rises to $\frac{1}{8}$-in. or $\frac{1}{4}$-in. above the latter in a length of about 3 ft. 6 ins. Beyond this, the head is sloped so that the rails are again level at the heel. This usually involves vertical bending of the switch rails, which is objectionable and hard to regulate exactly. Wear of rails, tie-plates and ties also soon eliminates minute adjustments. In one form of switch, the switch rail is at the required elevation for its full length (except that it is planed off at an incline for about 6 ft. at the point), the elevation being run out in the lead rail. Some roads, however, put the two rails at the same level; and this is entirely satisfactory when excessively worn wheels are not allowed to remain in service.

Switch Locks.—Devices to lock the switch rails in position are not much used, except for switches equipped with interlocking apparatus. In this case, the switch is very generally locked in either position by a bolt engaging with slots in the head rod. (See Signaling and Interlocking.) The Delaware, Lackawanna & Western Ry. uses for facing switches a lock rod which is parallel with the head rod and has two lugs which rise above the level of the rail base; these lugs engage the switch and stock rail on one side when the switch is set for the main track. A treadle on the switchstand revolves the rod by a crank and link connection, thus freeing the rails and allowing the switch to be opened. It is locked automatically when closed. The Emery switch lock is a small device placed on the tie, and automatically locks the rails together when the switch is closed. It is released by an ordinary switch key. Half a turn of the key allows the switch to be thrown without locking, to save the inconvenience of unlocking for every movement when switching cars. The key cannot be withdrawn, however, until the switch is again closed and locked,

Switch Guard Rails.—These are sometimes placed close in front of the switch points to guide the wheels into position to take the switch properly. They are principally used at turnouts from main-track curves to guide the wheels in the reversal of the centrifugal motion of the train and to prevent undue wear on the switch rails. On curves of 4° the Norfolk & Western Ry. uses the Barret-Burton switch, with one rail longer than the other and a guard rail on the inside of the main-line curve, as wheels tend to run to the high side of the track. This rail is 8 ft. long, with its head close to the switch point. It is straight for 3 ft., with a flangeway of $1\frac{3}{4}$ ins.; at the head it flares in 10 ins. to a clearance of $3\frac{3}{4}$ ins.; at the heel it flares in 4 ft. 2 ins. to a 4-in. clearance. The Philadelphia & Reading Ry. uses a 15-ft. rail, straight for 9 ft., with $1\frac{3}{4}$ ins. flangeway; the front end is curved for 12 ins. to a 4-in. clearance; the rear end flares for 5 ft. to a 5-in. clearance. Another plan is to place a single 10-ft. guard rail on the side opposite the turnout, this rail having its end 6 ins. from the switch point and giving a flangeway of 3 ins. at the heel and $1\frac{3}{4}$ ins. at the toe, the throw of the switch being $4\frac{1}{2}$ ins. The Pennsylvania Lines and the Southern Pacific Ry. use two 6-ft. straight guard rails. The latter gives a 2-in. flangeway, and on curves with widened gage these rails are 2 ins. and 4 ft. 6 ins. from gage side of outer rail. In switches on the sharp right-angled curves of the Chicago elevated loop, a guard rail is placed close to the stock rail on the side of the curve, and is extended back of the point of the switch rail. When the switch is set for the curve, the switch rail lies against the guard rail and is thus firmly supported to resist the blows from the wheel flanges in taking the curve. The Channel switch, Fig. 53,

has a guard rail about 9 ft. long, bolted to the inside of each switch rail, with the proper flangeway provided by spacing blocks. The flaring ends of the guard rails extend beyond the switch rails, and have the head rod attached to them.

If very heavy switch rails were bolted up tight at the heel splices, they would not move freely. In the 100-lb. switches of the Southern terminal at Boston, two of the bolt holes in each rail are reamed out to 1⅜ ins., and a heavy gas-pipe thimble is put over the bolt through the rail. The thimble is long enough to

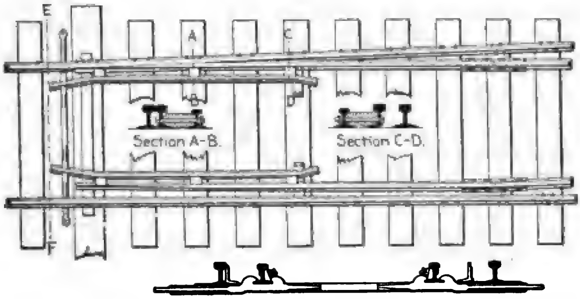


Fig. 53.—Channel Switch.

take the pressure on the angle bar and prevent pinching the rail. This allows the switch to move freely and yet leaves no loose nuts. The spread of the rails at the heel is often a little too wide, but the Bryant device used in split and slip switches and movable-point frogs at the above-mentioned terminal insures the proper spread and also prevents creeping of the switch rails. It consists of a splice trough or channel, 10 ins. long and 3 ins. wide, made of varying width to fit the angle between the rails. This is bolted between the angle bars of adjacent rails, or between the web of the stock rail and the splice bar of the heel joint. Stop lugs are sometimes bolted to the web of the switch rails, about 7 ft. to 10½ ft. from the point, so as to bear against the web of the stock rail when the

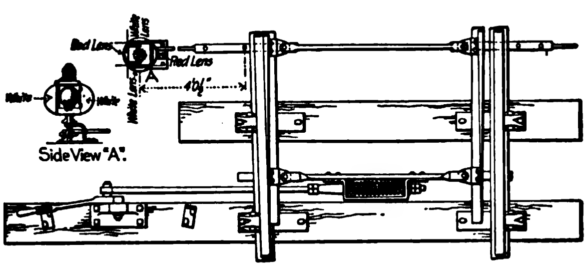


Fig. 54.—Lorenz Switch, with Ground Lever.

switch is thrown. Rail braces are generally placed outside the stock rail on at least two ties at the point, and sometimes back as far as the switch rail bears against the stock rail. It is a good plan to put a tie-rod or bridle rod just in front of the switch, to prevent any widening of the gage, and also to use a long slide plate on the first tie, extending across the track, as already noted.

Automatic Switches.—In the Lorenz "automatic" switch, Fig. 54, the connecting rod from the switchstand is fastened to a strap surrounding a stiff spiral spring carried by the head rod. The rod passes through the spring, which is

stiff enough to make a rigid connection when the switch is operated from the switchstand in the usual way. If set for one track, and a train trails upon it from the other track, the wheel flanges will force the switch rails over by compressing the spring, so that the train is not derailed and the switch connections are not broken. This type of switch is now very little used, and the question of allowing trains to trail through closed switches is discussed farther on, under the head of "Switchstands."

Slip Switches.—These are used at the intersections of diagonal tracks, where there is no room for an ordinary switch and turnout. The curves are necessarily very sharp, but the switches work very effectively in practice, and are largely used in yard work. A double slip switch is shown in Fig. 55. Such

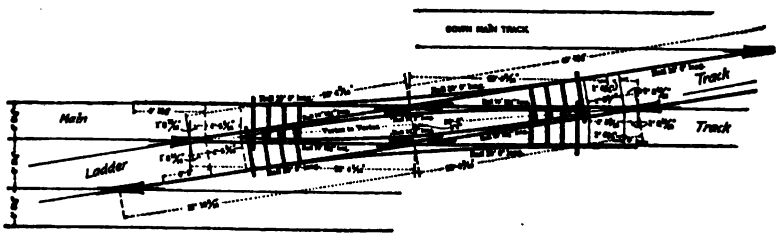


Fig. 55.—Slip Switches.

switches are not often used for main-track connections, but at the Germantown Junction (Philadelphia) of the Philadelphia & Reading Ry., where the four-track line diverges to form two double-track lines, there are slips 112 ft. long, having No. 15 frogs and 28-ft. switch rails, so as to give easy and safe passage for high-speed trains.

Three-Throw Switches.—In some cases, two turnouts diverge at the same point, requiring a crotch frog in the middle of the track, where the lead rails intersect. When permissible, it is better to set one switch a little in advance of the other, thus keeping the switch rails distinct, though this arrangement throws the crotch frog off the center line of the main track.

Switches with Continuous Main Rails.—With the ordinary split switch the main rail on the turnout side is broken or interrupted. The continuous rail follows the turnout, and the switch rail makes the connection with the main-line rail. There are, however, some special switches which avoid any break in the main-line rail. One of these is the Wharton switch, Fig. 56. When set for the siding, the grooved switch rail (A), 8 or 9 ft. long and slightly inclined, raises the outer wheels 1½ ins. above the main rail, its heel bringing them upon the raised lead rail of the turnout. At the same time, the elevating rail (B), on the outside of the main track, engages the outside of the treads of the inner wheels and raises them in the same way. If trailed through from the siding when set for the main track, the wheels run upon grooved castings (C) and (D), the latter of which guides the inner wheels over the main rail, when the flanges drop into place. If trailed through on the main track when set for the siding, the wheels open the switch by forcing back the pivoted guard rail (E), which rests against the main rail and is connected with the operating shaft (F) of the switch. The inside guard rail (G) should be not more than 2 ins. from the main rail, so as to force the wheels to mount the elevating rail (B) and keep them in position until the flanges have cleared the main rail. The elevating rail should also be set

close to the main rail. In a modified form, ordinary rails replace the grooved rails. Owing to the sharp elevation of the switch rails this device is best adapted for lay-over sidings, etc., which are used only a few times daily and at speeds of not over 20 miles an hour. In the MacPherson switch, when set for the siding, the switch rails (which are slightly higher than the main rails) engage with the wheel treads, the inner switch rail lapping over the main rail. The wheels are thus raised sufficiently for their flanges to clear the main rails. This switch is the standard pattern on the Canadian Pacific Ry., and is used in connection with the MacPherson frog or frog substitute which is described farther on.

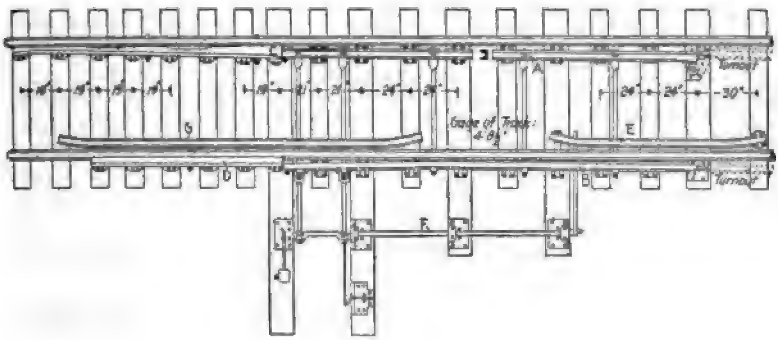


Fig. 56.—Wharton Switch.

Facing and Trailing Switches.—Any switch is a facing switch to trains running towards the point, and a trailing switch to those running towards the heel. In order to reduce the danger of derailment incident to facing switches, especially with high-speed traffic, some double-track roads make their main-line turnouts with trailing switches as far as possible. In such cases, a train taking the sidetrack must trail through the switch, and then back through it as a facing switch. This is a very important arrangement, and is being adopted in many cases as the result of accidents due to misplaced facing switches. It is not practicable or advisable in all cases; for instance, on a down grade where a heavy train would have to be started and backed up grade through the switch.

Derails.—To prevent a car or train on the sidetrack from fouling or running onto the main track, a derailing switch with stub or split rail is placed on the outer rail of the sidetrack, being open (as a derail) when the switch is set for the main track. This should be interlocked with the switch. The Delaware, Lackawanna & Western Ry. uses a 15-ft. switch rail. The sidetrack may be continued as a stub track beyond the derailing switch. This is somewhat more expensive, but prevents actual derailment. A derailing block or simple stop block is sometimes used in similar cases, generally on sidetracks where cars are left standing. These prevent the cars from being accidentally or maliciously moved so as to foul the main tracks. They are usually interlocked with the switch, and lie on the siding rail when the switch is set for main track. Derailing switches at grade crossings stand open on one track when the signals are set for the other track. At interlocking plants where a derailing switch is not desirable, a device resting on the rail head may be used to derail a train passing a "stop" signal. (See Signaling and Interlocking.)

Frogs.

At the intersection of the main and sidetrack rails, the rails must be cut to allow the passage of the wheel flanges. At this point is inserted a frog, which provides the necessary gap, with means for carrying the wheel treads and guiding the wheels. This is shown by Fig. 49. Frogs are now almost universally made of steel rails planed to shape, as shown in Fig. 57, the dotted lines indicating the rail connections. The shorter rail of the tongue should not be planed to a point, but its end should be about $\frac{3}{4}$-in. wide and dovetailed into the side of the longer rail. Usually the short point rail is placed on the turnout side, but in some makes it is placed on the main track, it being claimed that this is the stronger arrangement, and the one which will best withstand the destructive effect of hollow tires.

The back of the frog, behind the point or tongue, is called the heel. The space between the tongue and the wing rail on each side is the flangeway or flange space, in which is usually placed a filler between the webs of the rails. Beyond

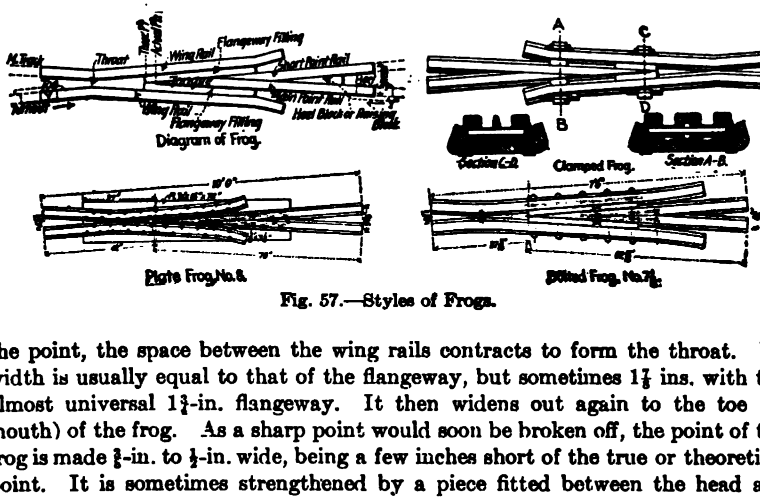


Fig. 57.—Styles of Frogs.

the point, the space between the wing rails contracts to form the throat. Its width is usually equal to that of the flangeway, but sometimes $1\frac{7}{8}$ ins. with the almost universal $1\frac{3}{4}$-in. flangeway. It then widens out again to the toe (or mouth) of the frog. As a sharp point would soon be broken off, the point of the frog is made $\frac{3}{8}$-in. to $\frac{1}{2}$-in. wide, being a few inches short of the true or theoretical point. It is sometimes strengthened by a piece fitted between the head and base of the rail and welded against the web before the rail is planed. The base of the tongue rail should be left the full width at the point, the base of each wing rail being cut away to allow of the rails being brought close together. A raising block should be inserted in the angle of the heel, to raise the outer flange of a hollow tire and prevent it from exerting a bursting effect by wedging in this angle. This block may also serve as an anchor block, being spiked to the tie to prevent creeping. The frogs should be carefully laid and bedded level on the ties, with plenty of good ballast underneath, as they are subjected to very severe blows. They should not be spiked to a gage $\frac{1}{4}$-in. or $\frac{1}{2}$-in. slack, or wide, as is sometimes done, unless they are on curves where the gage is correspondingly widened. In other words, the gage at the frog should be the same as that of the track in which it is laid.

At the heel of the frog are spliced the rails running from the tongue rails to the sidetrack, while at the toe of the frog the lead rails running to the switch are spliced to the wing rails. In the diagram in Fig. 57, the head of the right-hand

wheel (running to the left on the main track) will engage with the upper wing rail and the main-track lead rail. The left-hand wheel (running to the right on the turnout) will have its flange caught by the frog point and will be carried to the turnout rail at the heel of the frog. The frog should be of ample length, to allow of proper splice connections at the ends, especially as it is now often necessary to put an insulated joint at the frog. For this reason one rail at each end is sometimes made about 2 ft. longer than the other, so that the joints will not foul each other. In some frogs also a filler block is placed at each end, fitted between the rails and extending beyond their ends, so that the lead rails rest against and are bolted to the block.

Uniform bearing of the wheels on both frog point and wing rail can only be obtained by careful work. When both point and wheel are new, the bevel on the outer edge of the tread throws all the bearing on the frog point. A wing rail has the same effect when it is badly worn by false-flanged wheels, is bent vertically, or yields under the load of the wheel. In such cases the width of flangeway is not of much importance. On the other hand, many frog points, with insufficient support, "duck" as the wheel approaches, leaving the wing rail to carry all the weight, and this is aided where the rail forming the frog point has a very narrow flange and no base support. In such cases, the width of tread bearing is important, to carry the wheel firmly until the depressed portion of the frog point has been passed. Hollow tires also prevent simultaneous bearing. It is desirable to ignore the end of the frog point as a bearing, and to use a narrow flangeway and a small limit in wheel gage. This is referred to later in regard to the relations of wheels to frogs and guard rails. The destruction of a frog is due mainly to the shocks it receives, making it loose, and then increasing the wear on such a loose frog. The severest strain is generally assumed to be the blow upon the point, but it is probable that the lateral blow on the inside of the wing rail by the false flange of a trailing wheel, and the wedging action of a similar wheel at the heel (unless a raising block is used) are even more destructive.

One of the most important improvements in modern frog construction is the use of hard steel blocks or inserts to take the wear at the points of greatest wear. These are usually manganese-steel castings to form a facing for the wing rails at the throat. In some cases the frog point also is of the same material, though it has been objected that this will tend to cut the wheels. The character of the steel is similar to that of the track and switch rails already mentioned. The blocks must be very accurately made, as the metal is so hard that it can be finished only by grinding. They are secured in place by dovetailing and by keys or bolts; sometimes also by having molten babbitt metal poured between the rails and castings. These frogs will outlast five to ten ordinary frogs, but are much more expensive, and are only economical under certain conditions. A No. 8 frog of this kind with 85-lb. rails, on the Pennsylvania Ry., remained in the track over 4 years at a point where the life of an ordinary Bessemer steel frog was 3 months. The wear at the point was then $\frac{5}{16}$-in., and after grinding to surface and other slight repairs it was put back into the track. Frogs of 100-lb. high-carbon steel rails on the New York Central Ry. last from $2\frac{1}{2}$ to 3 years where those of softer steel wear out in 6 to 8 months.

The number of a frog indicates the spread of the angle included by the tongue rails, the spread in a No. 8 frog being 1 in. in 8 ins. The number may be determined in various ways: (1) Measure the distance between points where the width over gage lines is 2 ins. and 3 ins.; this distance (in inches) will give the frog

number; (2) Divide the length on gage line, from heel to true point, by the width over gage lines at the heel; (3) Take the sum of the width over rail heads at the heel and between rail heads at the toe, and divide this into the length on gage lines from toe to heel. The frog number is equal to the reciprocal of twice the sine of half the frog angle. The frog angle is that included by the tongue rails. Table No. 11 gives the angle of the frog numbers generally used, together with the degree of turnout curve from a tangent. A right-hand frog is for a turnout to the right, as seen by a man standing in front of the switch. A crotch frog is placed at the intersection of the lead rails of a double turnout (with a three-throw switch), and its number is equal to that of the main frog multiplied by 0.707.

TABLE NO. 11.—FROG NUMBERS AND ANGLES.

Frog No.	Frog angle.		Turnout curve.		Frog No.	Frog angle.		Turnout curve.	
	degs.	mins.	degs.	mins.		degs.	mins.	degs.	mins.
5	11	25	24	03	11	5	12	4	58
6	9	32	16	40	12	4	46	4	10
7	8	10	12	17	14	4	05	3	04
8	7	10	9	23	15	3	49	2	40
9	6	22	7	25	18	3	11	1	52
10	5	44	6	01	20	2	52	1	28

It is desirable to have as few sizes of frogs as possible in regular service, and the general practice is to have but two or three standard numbers, using special frogs where necessary. When standards are adopted, they should be introduced as rapidly as possible to replace odd sizes and numbers. If three numbers are made standard, they should be such that the lesser numbers will fit as crotch frogs of double turnouts, but such turnouts should not be used unless for special reasons. Nos. 7 to 10 are those in most common use. No. 4 is sometimes used for very sharp turnouts to warehouses, etc., but can be used only by switch engines with short wheelbase; its lead or turnout curve is of 150 ft. radius. A No. 5 frog is about the sharpest used in ordinary practice, and is for sharp turnouts in yards. No. 6 (or better No. 7) is used for ladder track connections, so as to occupy as little length of track as possible. Nos. 7, 8 and 9 are generally used in yards; Nos. 9 and 10 are used in ordinary main track, and should be the minimum for main-line turnouts, crossovers, etc., which are frequently used by road engines. Nos. 12 to 20 are used for high-speed turnouts, and Nos. 14, 18 and 24 at connections of single to double track.

The rigid frogs for 85-lb. rails on the Norfolk & Western Ry. are 15 ft. long, with a length of 8 ft. from point to heel and 7 ft. from point to toe. These dimensions are for Nos. 6 and 7 (special), and 8, 9, 10 and 12 (standard). In No. 15, the lengths are 9 ft. 6 ins. and 5 ft. 6 ins. respectively. The plates are ¾-in. thick; 22×42 ins. for Nos. 6, 7, 8; 20×42 ins. for No. 9; and 20×60 ins. for Nos. 10, 12 and 15. They have ¾-in. rivets, with the lower heads countersunk, and ¾-in. spike holes. The frog point is ½-in. wide and the flangeways are 2 ins. wide. The ties are spaced 18 ins. c. to c. On the Pennsylvania Lines the frogs ordinarily used are as follows: Nos. 15 and 20 spring-rail frogs for high-speed turnouts and crossovers; No. 10 spring-rail frogs for other main-track work; No. 7 rigid frogs for yard work. Where turnouts or crossovers require frogs below No. 7, preference is given to Nos. 4 and 6. The rigid frogs are of the bolted and clamped types. A 2-in. flangeway is specified, measured ⅝-in. below top of rail, and the fillers extend 4 ins. ahead of the point. Table No. 12 gives the dimensions of some frogs.

TABLE NO. 12.—DIMENSIONS OF RIGID FROGS.

(Bolted frogs.)

Frog No.	Length. Heel to point.		Length. Total.	Length. Wing rail.		Length. Filler.	Spread. Toe.	Spread. Heel.	No. of bolts.
	ft.		ft.	ft.	ins.	ins.	ins.	ins.	
4	5		8	7	2	$36\frac{1}{2}$	$8\frac{1}{4}$	$15\frac{1}{4}$	7
6	5		8	7	2	$36\frac{1}{2}$	$5\frac{3}{4}$	$10\frac{3}{4}$	7
7	5		8	7	2	$36\frac{1}{2}$	$4\frac{7}{8}$	$9\frac{3}{16}$	7
8	8		15	11	2	$36\frac{1}{2}$	10	$12\frac{1}{2}$	7
9	8		15	11	8	42	$8\frac{3}{16}$	$11\frac{3}{16}$	8
10	8		15	11	8	42	$7\frac{1}{4}$	$10\frac{1}{4}$	8
12	10		17	11	8	42	$6\frac{1}{4}$	$10\frac{1}{4}$	8
13	10		17	12	2	$47\frac{1}{2}$	$5\frac{11}{16}$	$9\frac{3}{4}$	9
14	12		19	12	2	$47\frac{1}{2}$	$5\frac{1}{4}$	$10\frac{11}{16}$	9
15	12		19	12	2	$47\frac{1}{2}$	$5\frac{1}{8}$	$10\frac{1}{8}$	9
(Plate frogs.)									
	ft.	ins.				(A)			(B)
5	4	6	7	5	6	$2\frac{1}{4}$	6	$10\frac{13}{16}$	3
7	5	3	8	5	6	$3\frac{1}{4}$	$4\frac{11}{16}$	9	3
9	6	4	10	6	$11\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{11}{16}$	$8\frac{1}{4}$	4
10	9	10	$17\frac{1}{2}$*	9	4*	5	$9\frac{1}{8}$	$11\frac{11}{16}$	4
12	9	0	14	9	6	6	5	9	5
14	10	7	$15\frac{1}{2}$	9	6	7	$4\frac{1}{4}$	$9\frac{1}{16}$	6

* The No. 10 frog has one rail at each end 2 ft. longer than the other; the wing rails are 9 ft. 4 ins. and 11 ft. 4 ins. long.

Column A gives the distance from actual point to theoretical point. Column B gives the number of horizontal rivets through the frog point.

Frogs are built up in various ways, as shown in Fig. 57. Bolted frogs have the parts held together by horizontal through bolts, $\frac{7}{8}$-in. or 1-in. diameter, iron or steel fillers being placed between the webs of the point and wing rails. Clamped or keyed frogs have yokes or clamps which pass under the rail and have their ends bent upward. Fillers are placed between the tongue and wing rails, and steel keys or wedges are driven between the wing rails and the ends of the yokes. One of the clamps should be placed at the frog point. The clamps may be flat or T-shaped forged bars, or bars $1\frac{1}{2}\times 3$ ins., set on edge, with the ends formed to fit the head, web and base of rail. The last are held in place by two rods hooked over the ends of the wing rails and passing through both clamps, being secured by spring keys or cotters. Plate frogs, with the rails riveted to a base plate, but with no fillers or horizontal connections, are not now much used in main track. They are, however, standard on the Delaware, Lackawanna & Western Ry. The plate is $\frac{3}{8}$-in. thick, 18 ins. wide, $5\frac{1}{2}$ ft. long for frogs of Nos. 7 to 9, and 7 ft. for Nos. 10 to 14. For lines of heavy traffic, bolted and clamped frogs are now very generally reinforced by a riveted base-plate or by two or more smaller plates which will fit between the ties. The New York Central Ry. uses plates attached by bolts with rail clamps. Where long base-plates are not used, iron plates should be laid on the ties to prevent the wear and cutting of the wood. The point should come upon a tie and have a plate under it to prevent "ducking" under the wheels. In filled frogs, the fillers should extend beyond the point and back to the heel of the wing rails.

Long frogs make a much better riding track than short frogs, and are more easily connected up, as already noted. A good length is 15 ft. for ordinary main track. Yard frogs may be from 6 to 10 ft. long. The curved lead (B–C, Fig. 58) is longer than the straight lead (A–C). If the straight lead of a No. 10 frog is 60 ft. (two lead rails, 30 ft. and 22 ft.; toe to point of frog, 8 ft.), then the curved lead will be nearly 2 ins. longer. This will bring the switch connecting rods 2 ins. out of square, which can be avoided by making the curved lead wing rail 2 ins. longer. If the wing rails are curved to fit the curve of the lead, they will make an easier riding track, but this is rarely practised,

though it should be done at main-track turnouts used at any but very slow speed.

Spring-Rail Frogs.—In all rigid frogs, above described, there is necessarily a jolt as each wheel crosses the flangeway, this jolt being very severe when wheels or frog are worn. In turnouts from first-class main track where the traffic on the turnout is light, the spring-rail frog is now almost universally used, and makes a smooth riding track, as it gives an unbroken main rail. It is therefore specially adapted for turnouts where the main line carries heavy and fast traffic, as it makes a safer and better riding track and diminishes the wear and maintenance work, the frog keeping in better surface than the rigid frog. The principle is explained by Fig. 58. The lead rails are A and B. The turnout wing rail, C, is hinged, and is normally held against the frog point by a spring, so that wheels, X, on the main track have no flangeway to cross, but have a continuous bearing. The main-track wing rail, D, is fixed. The wheels on the turnout, Y and Z, force back the spring wing rail C by the wheel flanges entering between the wing rail and frog point. The spring-rail frog is not generally required at junctions or in heavy yards, though it may be used for thoroughfare or open tracks in yards. At some junctions, however, where there is heavy traffic on both tracks, or where a double-track junction turnout runs into a single-track

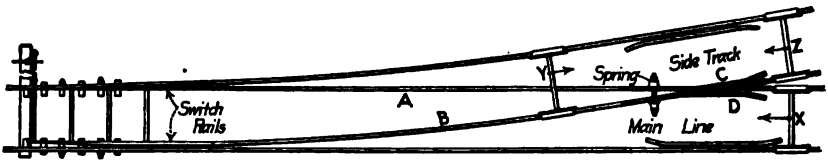


Fig. 58.—Diagram of Spring-Rail Frog.

branch, a double spring-rail frog is used. This has both wing rails movable and both normally resting against the frog point.

The spring is often placed near the throat, but it is generally considered better to have it nearer the free end of the rail, or opposite the frog point, while in some cases an additional spring is placed at the throat. The outward movement is about 2 ins., limited by stops. To prevent the end of the spring rail from rising when the wheels pass the throat, it is held down by hinged arms pivoted to the base plate and to an eye in a strap riveted to the web of the rail, or by bars projecting from the rail web and sliding in sockets on the plate. The frog point and the end of the spring rail should rest upon a base plate at least 3 ft. long, and the rail should fit against the point for a sufficient length to give a full bearing to the wheels. The standard No. 10 left-hand spring-rail frog of the Illinois Central Ry., with 85-lb. rails, is shown in Fig. 59. It is 14 ft. long, with the frog point at the middle, and has the spring opposite the point. The spring rail is 12 ft. 3 ins. long, with a movement of 2 ins., which is equal to the width at flangeways and throat. The top is planed down to allow the free passage of the false flange of a worn wheel, thus preventing such wheels (trailing) from forcing the rail outward. The rail is reinforced by a ¾-in. flat bar bolted to the web and bent to form four projecting plungers which ride in the guides or sockets and the spring box, as shown at F–F. The guides are bolted to the ⅝-in. base plates on the ties. In the open flangeway is a filler 16 ins. long, extending back from the frog point. A raising block is placed at the back of the point, and at each end is a filler block which extends beyond the frog rails, so that the lead rails are bolted against it, requiring only outside splice bars.

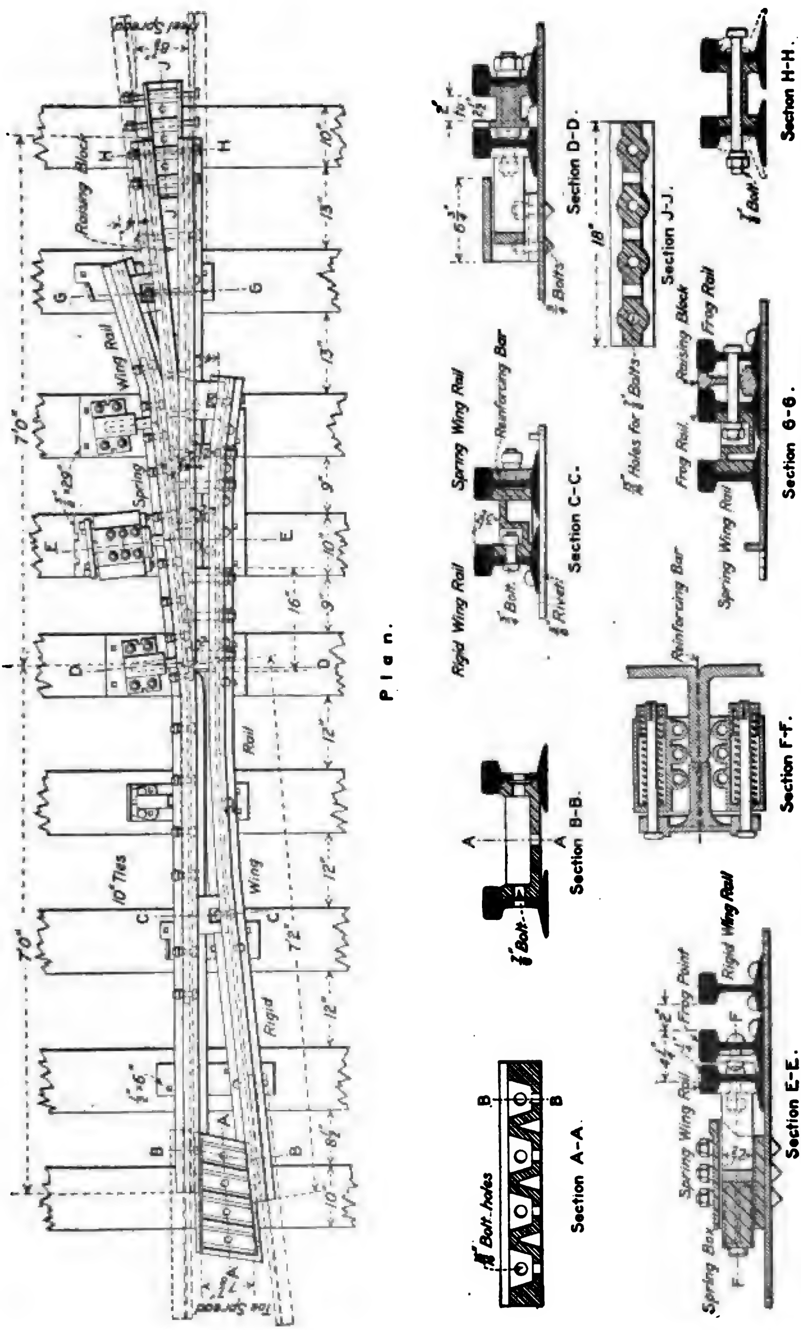


Fig. 59.—No. 10 Spring-Rail Frog; Illinois Central Ry.

A short guard rail or reinforcing rail outside the spring rail is sometimes provided as a means of extra security in case of fracture of the spring rail. In hinge-rail spring frogs, such as the Eureka frog (Fig. 60), the spring rail proper extends only from the heel to just beyond the throat of the frog, the part of the wing rail towards the switch being riveted to the base plate. An outer or "hinge" rail is bolted to the spring rail and hinged to the fixed part of this wing rail; these parts normally form a continuous running rail with a miter joint at the throat of the frog. In some frogs, the spring rail is arranged as in Fig. 60, but has an outside lug with vertical pivot at the throat end, the outside hinge rail being dispensed with. In the Vaughan frog, the arrangement is the same, but with the pivot at the heel and the spring opposite the frog point. In the ordinary frog the greater part of the spring rail is used as a part of the main track, but in the Vaughan frog only the end of the rail is thus used. The filling block is so shaped as to guide the wheel flanges in case of any failure of the spring,

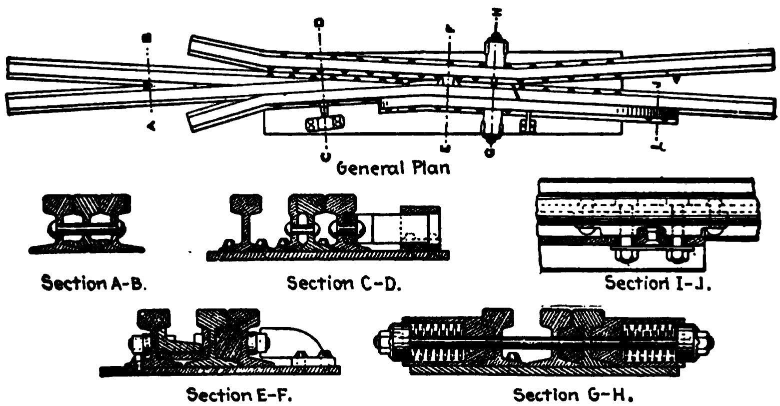


Fig. 60.—Eureka Spring-Rail Frog.

a rib on the block fitting under the head of the spring rail. Spring-rail frogs are as safe as rigid frogs in case of breakage, and accidents or breakages are very rare. With a worn frog or a hollow tire there might be possibility of the spring rail being forced out by a trailing main-track wheel to such an extent as to break the stops, so that the wheel will drop into the throat of the frog. In some frogs this cannot occur, and it may be prevented by beveling or grooving the top of the spring rail where the wheel treads engage it, or making that rail ¼-in. to ⅜-in. lower than the top of the frog, so as to clear worn wheels. The former practice is the better. The spring rail is also generally so made as to leave a slight flaring opening between it and the extreme end of the point, so that the wheel flange will be started in before pressure is put on the spring rail, thus relieving the frog guard rail. Devices have been introduced to lock the spring rail against the tongue when the switch is set for the main track, but these are rarely used. The objections as to the clogging of the spring rail are found in practice to be of little moment. Spring-rail frogs are largely used on roads which have much snow and ice to deal with, and in fact they are now almost the universal standard for main-track turnouts with relatively light traffic for the siding or branch.

Movable Wing Frogs.—In the Wood frog (Fig. 61), which has been used in yards, the two wing rails are bolted together at the throat, and connected by a

clamp behind the point, so that they move as one piece, sliding on a base plate. There is no spring, but the wing rails remain in either position, as set by the wheels. The Pennsylvania Ry. has used a somewhat similar yard frog, but having a spring on each side, 9½ ins. ahead of the point, with a filling block between the rails.

Frog Substitutes.—In view of the increasing number and speed of trains and the number of turnouts, several devices have been introduced to avoid the use of the ordinary frog, and to give an actually unbroken main-line rail. Some of these are in regular use. The principle is the same in most cases. The turnout lead rail is inclined sufficiently to raise wheels so that their flanges will clear the main rail, the lead rail having a gap through which the main rail passes. In this gap works a pivoted rail or a crossing piece of special shape, operated in connection with the switch, and resting upon the main rail when the switch is set for the turnout. An automatic connection is provided, so that a main-line train trailing through a switch set for the siding will throw the frog piece open and so set the switch in advance of the train. A careless man might sometimes throw a switch before a train taking the siding had cleared the frog, thus opening the

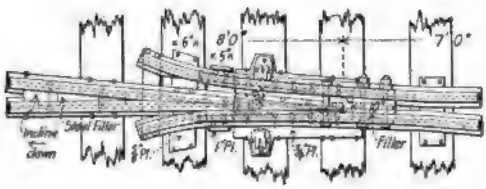


Fig. 61.—Wood's Movable-Point Frog.

frog and causing a derailment. A detector bar may therefore be applied, as in interlocking work, to prevent the switch from being thrown until every wheel of the train has passed the fouling point. It has been objected that the connections between switch and frog are liable to derangement by creeping or expanding track, or by a car coming off the sidetrack when the switch is set for the main track. These objections, however, have little force in view of the great extent to which interlocking apparatus and connections are in successful use. On some roads, also, all passing places are fitted with derails connected up to the switch, requiring longer connections than from switch to frog. The frog substitute has its limitations, the same as the spring-rail frog. It is not desirable for general use in yards, where quick switch throwing is necessary. For sidings in limited use, where the heavy wear of frogs (even spring-rail frogs) is disproportionate to the actual duty performed in carrying wheels in and out of the siding, it would be very desirable to have an unbroken main rail.

One of the first of these devices to be put into actual service was that patented in 1884 by Mr. C. B. Price, of the Pennsylvania Ry. The movable piece to fill the gap in the lead rail is a large casting, but the wing rail also moves, so that it lies against the main rail when the switch is set for the siding. Just beyond the heel of the switch is a spring guard rail fitted against the gage side of the turnout rail so as to be operated by the wheel flanges. When this is pressed back by the flanges its hooked lugs engage with sockets on the operating rod, which is then locked so that the switch cannot be thrown until the last pair of wheels has cleared the frog. The MacPherson device is very similar, and is largely used on the Canadian Pacific Ry. in connection with the MacPherson switch, already

described. It has shown but little wear, and the cost of maintenance has been small. Should a main-line train trail through the device when set for the turnout, the wheel flanges would mount the incline of the heel of the crossing piece; the wheels running along this casting and down another incline upon the main rail again. The guard rail opposite the crossing piece would hold the wheels over so that they cannot get on the wrong side of the main rail. When the head of such a train reaches the switch, each set of wheels would open it, but this would not throw the frog, owing to a spring connection in the switch rod similar to that of the Lorenz switch (Fig. 54). The frog cannot move until the switch lever is unlocked and thrown. The Coughlin swing-rail frog is also on the same principle, but the lead wing rail does not move. The only movable part is the frog piece or swing rail, which is made from an ordinary track rail instead of being a heavy casting. The end of this rail has the web and base cut away to let the head swing across the main rail, while the ends of the lead rail are riveted to a base plate which also supports the main rail, thus holding the parts in proper line and surface. The general design of these three devices is shown in Fig. 62, and a similar arrangement is used in connection with the Wharton switch, already mentioned.

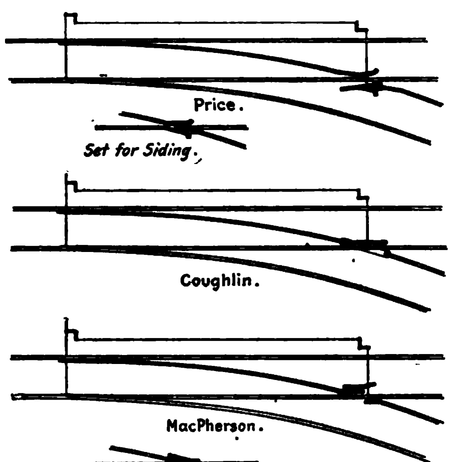


Fig. 62.—Frog Substitutes.

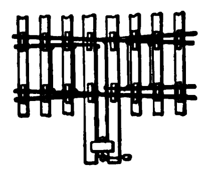


Fig. 64.—Movable-Point Crossing.

Crossing Frogs.—Where two tracks intersect (as at grade crossings), crossing frogs must be used to give a flangeway in both directions, and as there is no uniformity in the angles, the crossings have generally to be specially made for each case. They are built up of rails bolted together, with filling pieces between and heavy connections in the angles. They should be riveted to base plates at the corners or extending continuously under the rails. The rail ends may be beveled off to a miter joint at the frog point, or have one rail butted against the other. The inner wing rail, or guard rail, is usually continuous in crossings of 45° to 90°, but is sometimes stopped and flared out at each corner. Both methods are shown in Fig. 63. (See also Grade Crossings.) Where one track is the more important its rails may be continuous, having the heads grooved

to form flangeways for wheels crossing them. At crossings on busy tracks, a third rail is sometimes placed against the outside of the track rail to carry the false flanges of badly worn wheels and prevent them from battering the rails at the flangeways. The ends of these easer rails are inclined, so that wheels will take a bearing upon them without shock. Crossings may be built up without a joint between the frogs, but this makes a very heavy section for transportation, and does not admit of repairs without taking up the crossing. As a rule it is better to have a joint in two sides. The sharper the angle of crossing, the greater will be the wear on the frogs, due to the battering effect of the wheels in jumping over the flangeways. With an angle of less than 8°, or where

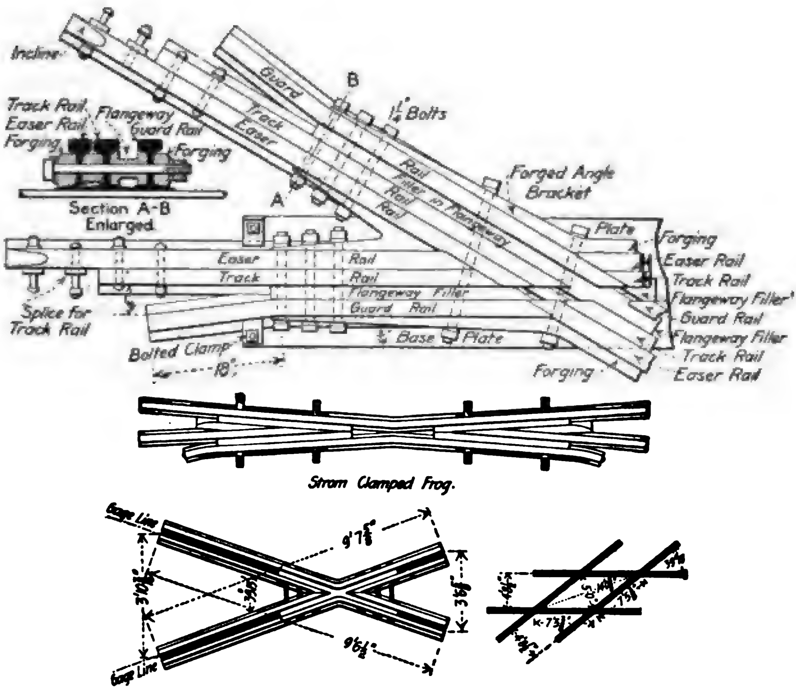


Fig. 63.—Crossing Frogs.

one or both tracks are on a curve, movable-point frogs may be used, instead of crossing frogs. In this case there will be two pair of short switch rails set toe to toe, as shown in Fig. 64, and operated simultaneously by a lever. A similar arrangement may be applied at the crossing of slip switches. In the Norfolk & Western Ry. practice, as exemplified by a crossing of 98°, the entire crossing is in two pieces. Under each corner, or frog, is a $\frac{3}{4}$-in. plate, 24×36 ins., to which the rails are secured by $\frac{7}{8}$-in. rivets, 4 ins. pitch, having the lower heads countersunk. There are strips outside the rails and fillers between the main and guard rails, all held together by three bolts in each leg of the crossing.

Where less important street railways cross steam railways, the flange filling is sometimes inclined so as to carry the wheels of the street cars over the crossing

on their flanges, thus giving an unbroken rail to the steam track. Where electric railways intersect steam railways, regular built-up crossings are generally used, made with ordinary rails, and having a reinforcing rail placed outside of and touching the main rail. In some cases the rails of the electric track and the reinforcing rails of the steam track are planed down $\frac{3}{8}$-in. or $\frac{1}{4}$-in. so as to clear all false-flanged wheels. This may be objectionable if four-wheel electric cars are run, but with double-truck cars very little shock is felt. The flangeway may be $1\frac{3}{4}$ ins. for the steam track and $1\frac{1}{4}$ ins. for the electric track, but interurban railways now use wheels approximating to the Master Car Builders' standard. In order to reduce the wear of crossings of this kind in city streets, the rails of the steam track are sometimes of manganese steel, made in a special section combining the running rail, reinforcing rail and guard rail.

Railway grade crossings are objectionable on account of the difficulty of keeping them in proper condition, due to the severe blows and shocks at the gaps for the wheel flanges. Devices have been invented to give a continuous rail to whichever track is to be used, but have generally failed through complexity or inability to stand the severe service. In the Leighton-Hansel crossing used on the Chicago, Indiana & Southern Ry., four grooved rail blocks of cast-steel move diagonally in the corners of the crossing. These are connected to a system of rods and bell-crank levers, interlocked with the signal plant, so that a continuous rail is given for the route which has a clear signal. Two extra levers are used, one operating the blocks and the other the lock. This has given satisfactory service, and in snow storms requires only the same attention as is given to the switches.

Frog Guard Rails.

Opposite the frog, and on the gage side of each of the running rails, is placed a guard rail to hold the wheels in line and prevent them from striking the point or getting on the wrong side of the frog point. They are sometimes omitted in yards on account of the liability of the men to stumble over them or to get their feet caught. They are usually 15 ft. long (sometimes only 7 ft. 6 ins. or 12 ft.), straight for 8 to 12 ft. at the middle, having 8 or 9 ft. of the length opposite the frog point. The ends are flared or curved out so as to bring the wheels steadily into the flangeway, the ends being about 4 ins. clear of the track rail. Rarely the rail is bent to a uniform curve and placed so that the narrowest part of the flangeway is opposite the frog point. This is based on the idea that the wheels should only be held over while passing the frog point and then immediately released, as to hold them any longer than this would result in extra wear of the frog and guard rail. The straight rails, however, are much to be preferred. The edge of the base is planed away to allow of the rail being placed close enough to the main rail. The rails are spiked to the ties and supported by rail braces, but should always be fastened to the track rails, so that the proper width of flangeway is permanently maintained. This may be effected by means of bolts or clamps, or a combination of these, with spacing blocks or fillers between the webs of the rails. Light rails may be used, being mounted on combination chairs and braces to give them the proper elevation, as is done on the Southern Pacific Ry.

The guard rails should be set and secured permanently in correct position in order to insure a safe and easy riding track, and to prevent excessive wear of frogs and guard rails. As already noted, the gage of track should be the same at

the frog as at the adjacent track, and it should be accurately maintained. The standard guard-rail gage is 4 ft. 5 ins. over the gage sides of the heads of wing and guard rails, or 4 ft. 6¾ ins. from gage side of frog point to gage side of guard rail, irrespective of the gage of track. The flangeway on tangents is usually 1¾ ins., sometimes 2 ins. for the turnout. On curves it will be increased by the amount of widening of gage of track. The Norfolk & Western Ry. specifies 1¾ ins. up to 8° curves, 2 ins. to 12°, 2¼ ins. for 12° and over. The importance of accuracy and uniformity of width is not sufficiently well understood by trackmen, and where the guard rail is independent of the main rail they will often merely guess at the width or vary it to suit their own ideas. The standard width should be insisted upon, and should be measured at the widest point of the rail heads.

The Norfolk & Western Ry. uses a 15-ft. guard rail (Fig. 65), straight for 7 ft., with a flangeway of 1¾ ins., flaring out to 2½ ins. at 2 ft. from the end of the

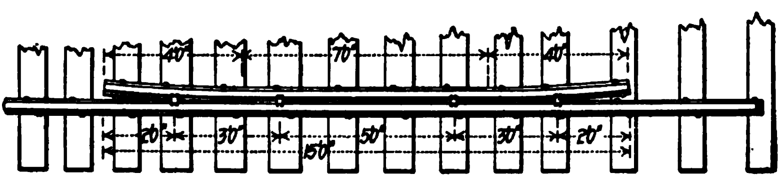


Fig. 65.—Standard Frog Guard Rail; Norfolk & Western Ry.

rail. The rail is spiked to the ties and bolted to the track rails with four bolts. The Pennsylvania Ry. uses a 15-ft. guard rail, straight for only 3 ft. at the middle, and then curved for 6 ft. to a radius of 9 ft. to give a clearance of 4 ins. at the end. The rail has 8 ft. of its length ahead of the frog point. The 15-ft. rail of the Delaware, Lackawanna & Western Ry. is straight for 12 ft. 8 ins., being curved for 14 ins. at each end to a radius of 3 ft., giving 3½ ins. clearance at the ends. It covers eight ties, and on each of the four middle ties is a ⅜-in. plate, 5×18 ins., carrying both rails and the rail braces. At the middle and 2 ft. 7 ins. on each side are three spacing blocks fitting under the rail heads and grooved for a flangeway 1¼ ins. deep. The rails are bolted together by a ⅞-in. bolt at each block. For frogs of 100-lb. rails, the Duluth & Iron Range Ry. uses guard rails of angle iron, ¾×6×6 ins., 20 ft. long, with 1¾ ins. flangeway for 8 ft. and then flaring out to a clearance of 4½ ins. at the ends. They are secured to the track rail by seven ⅞-in. bolts with cast-iron spacing sleeves.

With the ordinary guard rail, the wheel passing the frog is pulled into line by the other wheel on the axle, so that in case of a sprung axle or badly gaged wheels the wheel may not be put in proper line for the frog. Some frogs have been designed in which these rails are dispensed with, the frog itself having guards which guide the wheel by contact with the face of the rim instead of with the back of the flange. To effect this, it is necessary to raise the guards about 1 in. above the level of the running rails. The Conley frog of this type has been tried on the Illinois Central Ry., and the Graham frog on the Norfolk & Western Ry., both being in slow-speed or yard tracks.

Footguards.

Accidents frequently happen to railway employees from their feet getting caught under the rail heads in the angles at the heels of frogs and switches, and

at the flaring ends of guard rails. Being unable to free themselves, the men are often run over and either killed or maimed. These accidents are specially common in yards. It is a wise precaution to fill in such places, and in some States the use of footguards is required by law. Wooden blocking is the most common form, but has the disadvantage of soon becoming broken and decayed, and is apt to be left neglected in such condition. The Hart footguard, however, consists of a strip of wood of triangular section bolted to the inner side of the web of each rail. The outer (sloping) face extends from the bottom of the side of the rail head to beyond the edge of the rail base. Gravel or cinder filling is also sometimes employed, but soon settles down or shakes out so as to lose its efficiency. Metal footguards are preferable, and several forms are in use. The Norfolk & Western Ry. uses an iron bar $\frac{3}{8} \times 2\frac{1}{4}$ ins. (the height of the rail web) bent into a loop and driven between the rails. This is for rigid and spring-rail frogs, heels of switches, etc. The Atchison, Topeka & Santa Fé Ry. uses cast blocks forming combined footguards and spacing blocks. The raising block of a frog forms a footguard at the heel.

Relations of Wheels to Track.

The Master Car Builders' Association has adopted as standard a distance of 4 ft. $5\frac{5}{8}$ ins. back to back of flanges of car wheels. The Master Mechanics' Association allows from 4 ft. $5\frac{1}{2}$ ins. maximum to 4 ft. $5\frac{3}{8}$ ins. minimum for engine wheels. The minimum distance out to out of wheels (over the treads) is 5 ft. 4 ins. The standards are almost universally adopted, but in practice many wheels of improper gage are kept in service. These are very destructive to frogs, switches and guard rails, and are the probable cause of many "unexplained" derailments at such parts. Similar trouble is caused by the use of cheap wheels having thick and irregular flanges, which do not conform to the standards of the Master Car Builders' Association. In 1906, this association adopted a wheel section with stronger and thicker flanges. The increase at the point measured for gage of track does not exceed $\frac{1}{32}$-in. ($\frac{1}{16}$-in. for a pair of wheels), and this is negligible in view of the variations due to wear of rails and wheels. Such wheels can run through present clearances without difficulty. The flange is $1\frac{1}{8}$ ins. deep and $1\frac{1}{8}$ ins. thick, with a fillet or throat of $\frac{11}{16}$-in. radius; the tread is $3\frac{5}{8}$ ins. wide, with an inclination of 1 in 20 for $2\frac{3}{8}$ ins. from the throat.

It is an expensive practice to keep in service locomotives having worn or hollow driving-wheel tires, as the false flanges of such wheels are seriously destructive to frogs and switches, lead to much expense in track maintenance and repairs, and are liable to cause derailment. Worn blind tires, owing to their width, exert a powerful bursting force on frogs, switches and guard rails, which parts are not designed to stand such strains. Badly-worn tires on new rails with wider or flatter heads than the old rails, will slip and cause the engine to roll, to the detriment of the track and the reduction of the efficiency of the engine. Switch engines are often allowed to run with tires very badly worn, causing excessive wear of the track, and making it almost impossible to maintain the yard tracks in proper condition. If complaint is made, the motive-power department is apt to claim that the engines cannot be spared to go into the shops, but on many roads the departments work in harmony and the wear is kept within reasonable limits. Tire-dressing brakeshoes, which wear on the whole width of the tread and also on the flange, are a great factor in increasing the mileage of the wheels before turning is necessary.

The permissible limit for depth of wear of tires in regular service should be ¼-in. for road engines, and ⅜-in. for switch engines. It is not of much use to distinguish between passenger and freight engines, as they are frequently used in similar service, but the ⅛-in. limit might well be set for high-speed engines. The limit for depth of flange should be 1½ ins. for road engines and 1⅝ ins. for switch engines. The present limit of wear allowed by different railways ranges from 3/16- to ⅜-in., though wheels worn ⅝-in. hollow are sometimes met with in practice. On the Chicago, Milwaukee & St. Paul Ry. the limit of wear for driving-wheel tires in any service is ¼-in., but it rarely exceeds 3/16-in., except occasionally on yard engines, and then only for a short time. The roadmaster should have a tire gage, somewhat similar to the M. C. B. flange thickness gage, and promptly report any engines whose tires are worn beyond a proper limit and are damaging the track. By putting a straight edge across the tread, the depth of groove can be measured with a rule. A gage used on the Chicago, Burlington & Quincy Ry. consists of a steel plate with one edge formed to the standard outline of a new tire. This plate has a slide moving across it, with graduations on the slide and plate, as on a curve elevation gage. The gage is set on edge against the tire, fitting the flange and tread, and the slide pushed out until it touches the bottom of the worn groove, the scale showing the depth. The Keen gage has a number of small square pins in a row between two plates. The frame is set across the tire, the pins being allowed to drop freely and then clamped, so that when the gage is removed the pins show the contour of the worn tire. The measurements may be reported by the roundhouse foremen monthly, and the results tabulated, varying by 1/32-in. or 1/16-in.

Switch Ties and Timbers.

Switch timbers or switch ties of varying length are generally used, carrying the main and turnout rails of both tracks, as shown in Figs. 66 and 67. On some roads ordinary ties are used, alternating for the two tracks, as in Fig. 68. The former plan looks better and makes a more solid connection between the tracks. The long ties are somewhat difficult to renew, and have generally to be renewed in sets. The alternated ties give a closer support to the lead rails, but it is more difficult to tamp the separate ties to an even and uniform bearing for all rails. Switch timbers should be of the same thickness as the ties, and not less than 7 or 8 ins. wide on the face. Some roads have them 9 and 10 ins. wide, to give a good bearing to the curve lead rails, as the sharp curve makes them liable to cut into the ties along the outer edge of the rail base. It is better to prevent this cutting by the use of metal tie-plates, which are also frequently used to replace rail braces on turnout curves. The timbers should be spaced about 20 to 24 ins. apart, c. to c., not less than 8 ins. apart in the clear, but the spacing must be varied to fit the rail joints and to get a tie under the frog point, or as nearly under as a yoked frog will permit.

The required length of the timbers is ascertained by taking the difference in length (in inches) between the last standard tie at the switch and the last long tie beyond the frog, dividing this by the number of ties to be placed between them, and adding the amount thus obtained to the length of each tie, starting from the heel of the switch. This arrangement, with every timber cut to length, is shown in the Erie Ry. turnout (Fig. 66). Very frequently, however, instead of using a different length for each timber, the timbers are made in groups of the same length to the nearest 6 or 12 ins. This is done by the Southern Pacific Ry.,

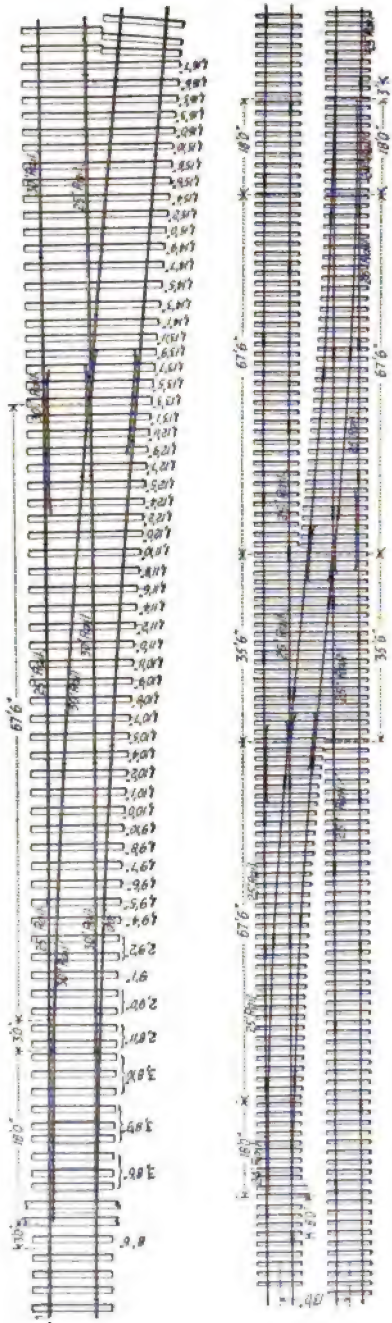


Fig. 66.—Arrangement of Switch Timbers at Turnout and Crossover; Erie Ry.

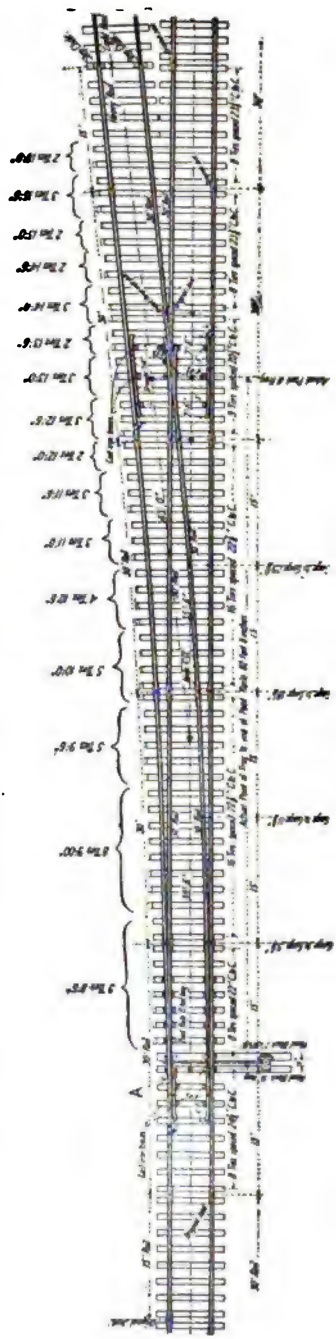


Fig. 67.—Turnout; Southern Pacific Ry.

as shown by the dotted lines in Fig. 67, but on that road after the ties are laid their ends are cut off parallel with the sidetrack rail, as indicated, which seems to be entirely unnecessary, involving useless labor and time. This turnout is for a No. 9 spring-rail frog, and tracks 15 ft. c. to c.

The last long timber should not exceed 16 ft. in length, though for crossovers on double track the middle timbers are often made long enough to take both tracks. A practice sometimes followed is to have a plank about 1×10 ins., 16 to 18 ft. long, with the lengths of the several timbers scribed and marked upon it. This is used as a gage in sawing the timbers to length before laying, but it is better to have them sawed to specified lengths at the mill, if this can be done. To ascertain the length of timbers for a three-throw switch, subtract half the length of the standard tie from the length of the switch timber for a single switch, and then multiply the remainder by two. Most roads have fixed tables or bills of material for switch timbers, which are issued to the foremen. The ties or timbers should be carefully laid on good, well drained ballast, and

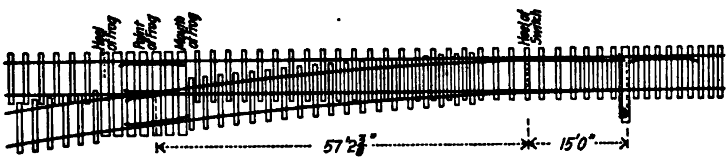


Fig. 68.—Turnout Laid on Ordinary Ties.

firmly tamped, especially under the frog, except that where plate frogs are used the ties may be set a little low, or allowed to settle, to allow for the thickness of the plate. This is better than cutting the ties to receive the plate. In Table No. 13 are given examples of bills of material for switch timbers; sometimes these bills give the number and length of each timber in consecutive order. The arrangement of ties at track crossings is noted in Chapter 9.

Switchstands.

The switchstand contains the mechanism for operating the switch, and consists essentially of a frame carrying a vertical shaft (sometimes horizontal for yards) with a target at the top and a crank at the bottom. The switch-connecting rod is attached to this crank and to the head-rod of the switch. The shaft is turned by means of a lever hinged to it, the lever normally hanging down, and held by a lug or socket on the stand. When the switch is to be thrown, the lever is raised to a horizontal position and swung round, turning the shaft and crank and operating the switch. The lever is then in position to engage with another lug. This is the operation of two of the switchstands shown in Fig. 69. In some cases the crank is replaced by a bevel-gear rack and segment, while in others the lever operates a segmental spur gear at the top or base of the switchstand. In the latter case, the crank shaft and target shaft are separate rods, connected by the horizontal gears keyed to them, the lever being attached to the target shaft. In some yard switchstands, a spiral slot on a drum or barrel engages with a stud on the switch rod; or a drop lever working parallel with the rail operates a bevel gear. With the steady increase in the use of the block system and interlocking plants, there is a more general use of the interlocking system at main-line turnouts and yard entrances

and in passenger yards. In such cases the switches are operated from levers concentrated in a tower, but the subject of interlocking is too broad to be dealt with here, and only the ordinary switchstands operated by hand are referred to in this chapter. (See Chapter 14.)

TABLE NO. 13.—BILLS OF TIMBER FOR SWITCHES.

Southern Pacific Ry.

No. 9 spring-rail frog; tracks, 15 ft. c. to c.; timbers, 7×8 ins. or 7×9 ins., as ordered; headblocks, 7×10 ins. The lengths given are for 8-ft. main-track ties; for 9-ft. ties add 1 ft. in each case The table shows lengths where the longest commercial lengths are 22 ft. and 26 ft.

Commercial length, 22 ft.				Commercial length, 26 ft.			
No. of pieces.	Length. ft.	ins.	Remarks.	No. of pieces.	Length. ft.	ins.	Remarks.
1	16	0	Headblock, 7×10 ins.	1	16	0	Headblock, 7×10 ins.
3	16	0		3	16	0	
6	8	6		1	8	6	
3	15	6		3	15	6	
2	15	0		3	8	6	
2	14	6		2	15	0	
3	14	0		2	9	0	
2	13	6		2	14	6	
2	8	6		2	9	6	
3	13	0		3	14	0	
3	9	0		3	10	0	Cut from 19 pieces 24 ft. long.
3	12	6	Cut from 13 pieces 22 ft. long.	2	13	6	
3	9	6		2	10	6	
2	12	0		3	13	0	
2	10	0		3	11	0	
3	11	6		3	12	6	
3	10	6		3	11	6	
3	11	0		2	12	0	
3	9	0		2	10	0	
1	10	6	Cut from 5 pieces 20 ft. long.	2	10	6	Cut from 3 pieces 20 ft. long.
1	9	6		2	9	6	
2	10	0		1	9	6	
2	9	0	Cut from 2 pieces 18 ft. long.	1	8	6	Cut from 3 pieces 18 ft. long.
1	9	6		4	9	0	
1	8	6		2	9	0	Cut from 2 pieces 26 ft. long.
1	10	0		4	8	6	
61				61			

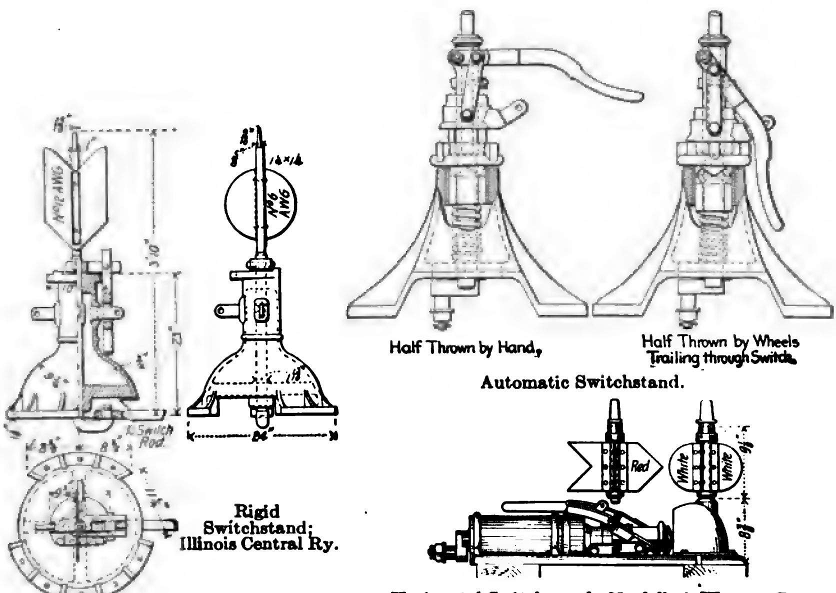
Philadelphia & Reading Ry.

No. 10 spring-rail frog; tracks, 12 ft. 1½ ins. c. to c.; all timbers 7×9 ins., except those marked (*), which are 8×9 ins.

Turnout								Crossover			
No. of pieces.	Length. ft.	ins.	Feet. B.M.	No. of pieces.	Length. ft.	ins.	Feet. B.M.	No. of pieces.	Length. ft.	ins.	Feet. B.M.
5	8	9	230	2	13	3*	159	10	8	9	460
5	9	0	237	1	13	6*	81	10	9	0	474
4	9	3	194	2	13	9*	165	8	9	3	389
4	9	6	200	1	14	0	74	8	9	6	400
3	9	9	154	2	14	3	150	6	9	9	308
3	10	0	157	1	14	6	76	6	10	0	315
3	10	3	162	2	14	9	154	6	10	3	323
2	10	6	111	1	15	0	79	4	10	6	221
2	10	9	113	1	15	3	80	4	10	9	226
2	11	0	116	2	15	6	162	4	11	0	231
2	11	3	119	1	15	9	83	4	11	3	238
2	11	6	121	3	16	0	252	4	11	6	242
1	11	9	62	1	16	3	85	2	11	9	123
2	12	0	126	1	16	6	86	4	12	0	252
1	12	3	64	1	16	9	88	2	12	3	129
2	12	6	131	2	17	0	178	2	16	0	168
1	12	9*	77	2	17	3	181	13	20	9	1,417
1	13	0*	78	..	..	..	.....	16	20	9*	1,992
Total				71			4,385	113			7,908

The distance from rail to switchstand varies considerably, but should give sufficient clearance from cars. A distance of 7 ft. on the engineman's or 8 ft. on the fireman's side is very general, but would be less in yards. Main-line switchstands have target rods 6 to 10 ft. high, so that the targets and lamps will

be prominent. Ordinary yard switchstands should be 3 to 5 ft. high, while low ground or dwarf stands may be 2 ft. high. Yard switchstands are sometimes horizontal, as in Fig. 69. Some roads use a high stand at main-track switches, 18 to 20 ft., which can be seen over the cars. They should not be high enough for the lamp to be confused with semaphore lamps. Where two or three switches near together open out from a main-track connection, the switchstands should be set at varying distances from the rail, so that the targets will not be in line; or should have the targets at different heights, increasing from that at the first switch. A simple device for unimportant yard switches is a drop-lever switchstand (Fig. 54) operated by a lever lying on the headblock. If little used, targets may not be required, and the lever may be secured by a padlock. Such switchstands should not be used for main-track switches.



Half Thrown by Hand. Half Thrown by Wheels Trailing through Switch.
Automatic Switchstand.

Rigid Switchstand; Illinois Central Ry.

Horizontal Switchstand; Norfolk & Western Ry.

Fig. 69.—Switchstands.

The Illinois Central Ry. has three standard sizes of rigid switchstands: 3 ft. 10 ins., 5 ft. 5 ins., and 7 ft. 1½ ins. high to the top of the rod. Where three switchstands come in line at one end of a station, the low stand is used at the first (or outer) switch, then the medium, and then the high stand. Where two come in line, the medium and high stands are used. Each has a green disk and red target, as in Fig. 69. On the high stand the disk is 17½ ins. diameter, of No. 16 steel; the target is 12×30 ins., of No. 12 steel. Targets and lamps are described below.

The switchstand is carried on one or two long ties, called the headblocks, so as to be kept in fixed relation to the switch, but for high switchstands the shaft carrying the lamp and target is frequently supported by collar bearings on a vertical braced post or a set of three or four inclined rods, the post or rods being fitted to a framed foundation independent of the headblock. In this

way the lamp is relieved from some of the shock and jar incident to the operation of the switch. The switchstand should be firmly bolted to well tamped headblocks, and no lost motion should be allowed, while the working parts should be kept true, clean and well oiled.

Automatic Switchstands.—To allow for trains trailing through a closed switch without injury to the switch, an automatic switchstand is frequently used. The mechanism may comprise heavy springs on the connections in the switchstand, or a clutch normally held closed by a spring, but forced open when the wheels exert a pressure on the switch rails (Fig. 69). In either case, the lower part of the vertical rod can revolve when subjected to heavy pressure at the switch connections, while the upper part remains locked in the switchstand. If a train in making switching movements should trail partly through a closed switch and then back up, the train would be split, the cars behind the switch keeping to the sidetrack, while those in front would take the main track. This would probably result in derailment, with damage to cars and switch, and such an accident would indicate neglect and carelessness on the part of the train crew and switchmen. To provide against this, switches have been arranged to remain in the position to which they are thrown by the wheels, but this is a dangerous plan and rarely followed. The automatic switchstand may be made so that the switch can be trailed through from either track when set for the other track, or so that it will be locked when set for the main track. In the latter case, a train trailing through from the sidetrack would break the connections, and show that the switch had been misused, as it is a dangerous practice for trains to thus run through a switch set for the main track. The automatic switchstand is safer than the automatic switch, already described, Fig. 54, as the latter can have the lever thrown even when the switch rails are not fully thrown, owing to obstructions between the switch and stock rails. In automatic switchstands this cannot be done. While there are certain places where the use of automatic switchstands is permissible (especially in yards, to prevent frequent damage), the better and more general practice is to adopt a rigid stand and to forbid the running of trains through closed switches.

Switch Targets.—The targets are usually of No. 10 to No. 16 sheet iron; of square, diamond, circular or other shape. The targets for the two tracks governed by the switch should be of distinct shapes. They should be kept clean and well painted, as in gloomy weather, or with smoke and steam blowing across the track, an engineman may easily mistake what he can see of a dirty red square to be a dirty white disk. They are usally painted two or three times a year. The targets may be shaped to show to which side the switch leads, and the stands for three-throw switches should have targets indicating for which track the switch is set. They should not be too large, or they will be a danger to brakemen hanging on the sides of the cars. On low stands, or pot signals, the targets may be attached to the sides of the lamp case, or to a rod rising above the lamp. The high stands for some main-track switches have a circular target for the main track, and a fixed red and white arm like a semaphore blade for the sidetrack. On the Pennsylvania Lines, the main-line switchstands are connected with standard semaphore signals, the running face of the blade being yellow, with a black band. This is good practice in view of the fact that the semaphore is practically the standard form for block and interlocking signals, and the same practice should be followed where interlocking plants or distant signals are used. As to the color of the targets, plain red and plain white are

usually the most distinctive, and can be seen at the greatest distance. A black spot on the white does not make it any more readily distinguishable, except against snow. Any white on the red tends to make it appear pink and consequently less bright and prominent, but at a short distance and with a dingy background the combination may be more prominent than the plain red. Red and white are most commonly used, though some roads use green and red or green and yellow (or white) for yards. On double track, the backs of the targets may be painted black. If the switchstands are painted white, or whitewashed, their positions will be more easily seen by the engineman, and the same applies to the signal posts of block signals.

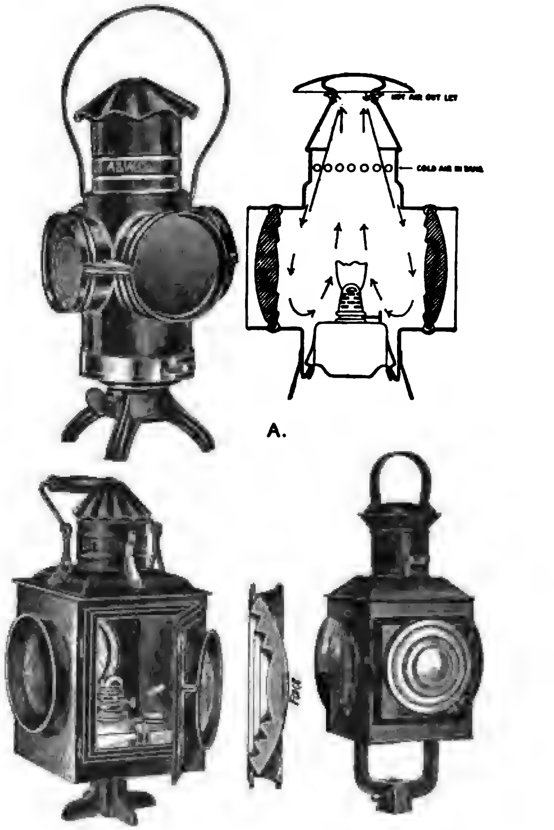
Inquiries made by a committee of the American Railway Engineering Association, as to practice in switch targets on 50 roads, produced the following information: (1) On double track, 43 roads use targets and lamps on both facing and trailing switches and 4 on facing only. (2) Targets for both positions are used by 38, and for "switch open" only by 12; most use targets of different shapes for the two positions. (3) A target in the form of a semaphore blade is used by 11 roads. (4) A distant signal interlocked with the switchstand of a facing switch is used by 31 roads. (5) A high tripod stand is used by 23 roads, so that the target can be seen over freight cars. (6) All 50 use a lamp to show when the switch is closed; white and green are used, but the majority favor green.

Switch Lamps.—The switch lamps should be of riveted sheet steel or galvanized iron, these being preferable to soldered tin. They are either square or round, and have generally hinged doors, which are preferable to slides. In some cases there is no door, the oil pot being put in and taken out from the bottom of the case, while the top is sometimes hinged to swing open. Side doors and slides should be air tight, and the ventilating openings so protected that the light cannot be blown out by the wind. The top draft system is usually considered the best. In this, the air supply is taken in at the top of the lamp (A, Fig. 70), and diverted by a cone to the sides; it rises at the center to the flame and escapes through the apex of the cone. There is said to be steadier draft and less collection of moisture than with the bottom draft system. In this latter, the air enters at the bottom of the case, a perforated plate above the openings preventing the air from blowing directly on the flame. This is claimed to have an advantage in keeping the oil fount cool. Kerosene is generally employed for the lamps, a better grade being employed in high than in low altitudes. Chimney glasses are not often used. There should be a peep hole and wick raiser in the outer case, so that the lamp can be inspected and trimmed without opening the door. A spring bottom or socket is also sometimes used to prevent the wick from being shaken down by the jarring of the switchstand.

The lenses should be of ample size and good design, so formed as to throw a direct beam of light of the greatest intensity, and not a diffused light. The lenses may be of plano-convex form (flat at the back and spherical on the face), but the best form has the back cut in concentric corrugations, as shown at A and B, Fig. 70. In some cases, however, the corrugations are on the face of the lens, as at C, Fig. 70. The ordinary size of lens is 5 or 5⅜ ins. for semaphores and main-line switchstands. A diameter of 8 ins. is sometimes employed for lamps at bridges, tunnels and crossings. The lamps for yard switches and dwarf signals may have 4-in. or 4½-in. lenses. Backlights may be 2 ins. diameter. With good lamps, ordinary lenses, and no reflectors, the lights will be

visible for from 1 to 3 miles in clear weather. They will be stronger and sharper with reflectors. Yellow lights cannot be seen as far as red or green. The prism glass reflector is being favorably considered for signal lamps; it increases the intensity of the light, and is free from the deterioration in reflecting power after long service, such as is experienced with metal reflectors. (See also Signals.)

To insure the lamp being in proper position on the switchstand, the socket or fork should be so shaped that the lamp can be put on only in one position.



A.

B. C

Fig. 70.—Switch Lamps.

If the socket on the lamp fits on the top of the vertical shaft of the switchstand, the top should be rectangular instead of square, or one corner of the socket may be filled up to fit a chamfered corner of the rod. The lamps should be kept clean, in good repair and properly trimmed, the lenses especially being wiped free from grease and dirt. The wick should rarely be cut with shears, but the charred crust may be scraped off with a match stick. The light should be turned down as soon as lighted, and in a few minutes gradually turned up to give the proper size of flame, being watched for a few moments to see that

it burns steadily and does not flare or smoke. When the light is extinguished the wick should be turned down to prevent waste of oil. Long-burning lamps with large founts are being extensively adopted, but should not be used for more than four to six weeks, as the wick will become clogged with impurities. They should be cleaned and trimmed every few days. An English long-burning lamp tried on the Lake Shore & Michigan Southern Ry. has a solid round wick in a slotted tube, around which is coiled the top of an auxiliary wick. The latter does not reach the flame, but feeds the upper end of the main wick. This will burn day and night for from 10 to 14 days, but should be trimmed and filled every week to keep a good light. The founts should not be continuously refilled, but every few weeks all the oil should be poured out. The burners should be occasionally boiled in water and soda. If the lamps are carried lighted from the section house they should be examined after being put in position on the switchstand. The filling and trimming of the lamps should be done on a shallow zinc-lined tray or shelf with raised edges to prevent waste of oil, and the oil cans may be set on a shallow tray filled with sand, to prevent the floor from getting oil soaked.

Red and green are the colors most generally used for switch lights, while some roads use green and white for yard switches. There is a strong tendency to avoid the use of white as the clear signal for main track, as station and street lamps are liable to be confused with white signal lights, especially at yards in towns. For main-line switchstands, the lamps show a green light in each direction when the switch is set for the main track, and a red light in each direction when it is set for the sidetrack. On some roads, however, the light is shown only in the facing direction, the lamp having only two lenses. This is specially the case on double track. The lamps are usually kept lighted from sunset to sunrise, and during foggy weather. On the Atchison, Topeka & Santa Fé Ry. all switch and signal lamps, and all lamp men, are under the charge of the Signal Department, and a standard pattern of lamp is used over the entire road.

Switch Protection.

Main-line switches are too often inadequately protected, and the unprotected switch is one of the great dangers to traffic. Periodically a careless or weary man leaves the switch open after a train or switch engine has entered the siding; or thinks he has left it open and hastily closes it when startled by the approach of a train. In either case there may be a collision or a derailment on the sharp curve of the turnout. In other cases, the switch is opened by mischievous or malicious persons, who have only to break a common switch padlock. A switch target and lamp are not sufficient protection for a main-line switch, whether used at high speed or not. The use of the common switchstand, unprovided with any safeguard, should not be permitted at main-track turnouts. On lines with heavy traffic, and not equipped with block signals, the turnouts (especially at passing sidings and similar connections) should be equipped with interlocking switch and signal plant (including distant signals), controlled by an operator in a tower. This is advisable not only for safety, but also to increase the facility of handling traffic, as a heavy train has not then to stop at each switch (for the brakeman to run ahead and operate it) and then pull slowly into the siding. Further particulars as to the protection of main-track connections will be found under "Sidings." Where the traffic does not warrant this expense, the switch should be provided with a distant

signal, automatically operated by mechanical or electrical connections from the switchstand, the switch also having a lock. Then the switchstand cannot be thrown to open the switch until the signal indicates "stop," and must be closed before the signal can again indicate "clear." The distance is usually from 1,000 to 2,000 ft., sufficient to enable a train to be stopped (or at least checked) before reaching the danger point. There are numerous devices of this kind available, and main railways use them to some extent, but it is desirable that their use should be more general. The Southern Pacific Ry. uses an electrically operated signal 2,000 ft. from the switch at all points not equipped with interlocking or block signals.

At sidings near stations, the switchstand may have an electric lock controlled by the signalman or telegraph operator. Where automatic block signals are used they serve to indicate open switches. The ends of double-track sections should be protected by electric locking, with distant signals and track circuits. When a train has passed the signal, the switch is locked until after the train has cleared the junction. The safety to traffic may be increased by reducing the number of switches in main track. This may sometimes be effected by putting in a drill track or siding from which spur tracks are run, the only switch in the main track being that which connects with the siding. On double-track roads, also, it is often possible to materially reduce the number of facing switches. At passing sidings, accidents often occur through an engineman pulling out without orders or thinking that the opposing or superior train (or its last section) has passed. For this reason, such sidings should be under some control. Further notes on this matter will be found under "Sidings" and "Signals." (See also Engineering News of March 28, 1907, and Sept. 21, 1905.)

Devices have been invented to enable a train to automatically close an open facing switch, but their use should never be permitted. They are wrong in principle in recognizing that such a dangerous feature as an open switch is to be expected and that a train may close it, regardless of conditions (which are of course unknown to the engineman). A device which automatically closes a switch after a train and so prevents it from being left open is more reasonable. One of the earliest forms of the latter was a switch operated by a weighted lever, which had to be held up to keep the switch open, but the men soon learned to prop this up and of course often forgot to release it. Another device was a cabin enclosing the switchstand, so arranged that a man could not open the switch without entering the house, and could not then get out as long as the lever was in position for an open switch. This was tried many years ago in this country and abroad.

CHAPTER 8.—FENCES AND CATTLEGUARDS.

Fences.

The numerous styles of right-of-way fencing in use by railways are due to local conditions and to the varying ideas of engineers and manufacturers, while some States have laws specifying the style of fence more or less in detail. The height should be at least 4 ft. 6 ins., and 5 ft. is preferable where cattle are kept. Board fencing is comparatively little used, except near towns and where snow

causes trouble. Strand and woven-wire fencing is largely used in open country, the latter especially for pasture and farm land.

Fence Posts.—Fence posts are largely of oak and chestnut (lasting about 9 years), locust (10), catalpa (12) and cedar (15). They are usually from 7 to 8 ft. long, 6 to 8 ins. diameter at the bottom and 4 to 6 ins. at the top. They are preferably round (not sawed or split), and should be stripped of bark. The lower part may be coated with pitch, creosote or other preservative to about 6 ins. above the ground line. They are set about 3 ft. in the ground, the holes being excavated by long-handled shovels, or by post-hole augers or diggers. On long stretches of prairie a small pile driver mounted on wheels has been used. The proper height above ground may be gaged by making the holes to a uniform depth as marked on the handle of the digger, or by means of a stick having a flat board to stand on the ground. On rocky or swampy ground, the posts may be mortised into sills 4 ft. long (made of old ties cut in half), and secured by braces nailed to the top or side of sill and the back or side of post. Rough A frames made of two posts with a plank brace at bottom may also be used (Fig. 74). End, corner, anchor and gate posts should be set 3½ to 4 ft. deep, and anchored by bottom planks with side cleats or inclined braces.

Concrete posts of various designs have been tried, but are not in general use, although a few railways use them extensively. Those on the Lake Shore & Michigan Southern Ry. are 5×5 ins., with four ¼-in. steel rods. Others 7 ft. long taper from 4×6 ins. to 4×4 ins.; the anchor and corner posts taper from 7 ins. to 5 ins. square. The concrete may be composed of 1 part Portland cement to 2 or 3 parts of gravel, coarse sand or stone screenings (from dust up to ½-in. size). The reinforcing consists of wire, rods, pipe, old rails or boiler tubes, etc. The posts should be left 24 hours in the molds, and then 24 hours in the molding room; they are then stored for 4 to 6 weeks, being protected from sun and wind and kept wet for from 1 to 4 weeks. Some posts, however, are made in place, the post hole forming the mold for the lower part. The inclined braces in end panels may be of concrete reinforced with a 2½-in. angle. The molds may be coated with soft soap to give the posts a smooth surface, and may have the corners filled with triangular strips to form chamfered corners on the posts. Projecting staples, wires, hooks, or cast-iron sockets for staples, may be embedded in the concrete to serve as attachments for the fence wires; holes may also be cored for fastenings and gate irons. The Union Pacific Ry. has used concrete posts in timberless country; the line posts are 4×5 ins. with a two-strand cable of No. 10 wire at each corner (eight cables in corner posts). Several of these are made at a time, the molds filling the bottom of a box in which the concrete is dumped. They are of cement and sand, 1 to 3, with cored holes for attachments. Metal posts made of old boiler tubes set in concrete bases (and filled with concrete) have been extensively and successfully used, especially in prairie country where wood is scarce and wooden posts are liable to destruction by fire. The Chicago, Burlington & Quincy Ry. makes about 20,000 of these every year. Metal fence posts, however, are not extensively used for right of way, but are used at station grounds, etc. They may be angles or tee-bars, driven into the ground or set in bases of concrete or burned clay. They may be slotted for the wires or have special clip staples.

Wooden Fences.—The most common type is the board fence, with posts 8 ft. apart. The boards are generally of pine, hemlock or other cheap wood, 16 ft. long, 1 or 1¼ ins. thick, and 6 to 8 ins. wide. They should all be of the same

size, with the bottom boards usually placed closer together than the upper ones, so as to stop small stock. The boards are placed on the field side of the posts, and each is secured by two or three nails. These are 10- or 12-penny nails, 3 or 4 ins. long, 69 or 62 per lb. If all the joints come on the same posts, a batten, 1 × 6 ins., may be nailed to cover them, but in general the joints are broken, and come on alternate posts. The Chicago, Rock Island & Pacific Ry. uses for station headquarters a board fence with posts 7 ft. long, 2 ft. 9 ins. in the ground, spaced 8 ft. c. to c. There are four boards 1 × 6 ins., 16 ft. long, breaking joints on alternate posts. Each is secured by two 10-penny nails at the ends and three at the intermediate post. The bottom board is 4 ins. from the ground, and the others are 4, 8 and 9 ins. apart. In some cases a cap board is laid flat on the top of the posts. When this is done, the top board may be omitted, but the standard board fence of the Michigan Central Ry., Fig. 71, has both cap and top boards. It is not often that the bottom board is laid on the ground as shown, but this is the legal railway fence in Michigan. In rail

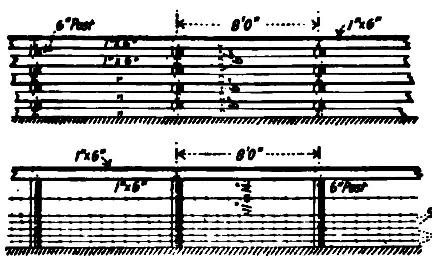


Fig. 71.—Board and Wire Fences; Michigan Central Ry.

fences, the posts are slotted to receive the ends of split rails, having the ends flattened to fit into the slots, where they either lie loosely or are secured by pins through the post.

Wire Fences.—These are extensively used, on account of their efficiency, safety from fire, and small amount of maintenance required. They are of two kinds: strand fencing and woven fencing. The posts may be from 8 to 16½ or 20 ft. apart (sometimes even 25 or 33 ft.). It is rarely advisable to exceed 20 ft., and with a spacing of over 12 ft. strand wires should be connected at intervals by vertical stay wires or wooden battens to maintain the proper spacing and stiffen the fence. Gate, corner and end posts must be well anchored and braced to resist the pull of the wire. The anchor may consist of two cross-pieces, one on the face (near the ground) and the other at the back (near the bottom). The brace is generally a timber 4 × 4 ins. or 3 × 5 ins., having one end let into the top of the brace post and the other into the next post at the ground line. The post may also be tied by heavy wires wrapped around its top and around the lower part of the next post. Very frequently the brace and tie are put in the same panel. In long stretches of unbroken fence there should be braced panels not more than ½-mile apart. In depressions, the lowest post should be anchored by a bottom board or cleats, so that the strain of the wire will not pull it out.

Strand wire fencing consists of independent lines of plain, twisted, ribbon or barbed wire. At one end, the wires are secured to an anchor post, while at the other end they are attached to spools in a special post, so as to allow of

adjusting the slack. Plain wire is generally No. 9 or 10 (306 or 255 lbs. per mile); vertical stays may be of No. 13. Ribbon wire is flat, usually twisted, and sometimes cut in barbs. Ordinary barbed wire has two strands twisted together, and wrapped at intervals of 5 ins. (3 ins. for hog wire) with short wires leaving 2 or 4 sharpened projecting ends. This weighs from 230 to 400 lbs. per mile (with wires of No. 12 or 12½). The wires are usually secured to the posts by 1½-in. staples, 72 per lb. (or for soft cedar posts 1¾-in. staples, 65 per lb.). On long panels, they may be stapled to a batten midway between the posts, so as to keep them evenly spaced and prevent them from sagging. Barbed wire fencing is objectionable in many ways, and its use is prohibited in some States, while many railways as well as landowners are opposed to its use. With this wire, and in fact with almost any fence of longitudinal wires, a top board should be used, so that horses and cattle may see the fence more clearly and so be prevented from running against the wire and being injured. Some roads cut the tops of the posts at an angle of 45° and spike on a top board or rail 2×4 ins. The standard wire fence of the Michigan Central Ry., Fig. 71, has six wires, a top board and a cap board.

The height of fence is usually 4 ft. 6 ins. The number of wires is sometimes as low as four, but generally five for ordinary work in open country; or as high as ten through farm lands. For hogs and sheep, there should be six wires in the first 24 ins., spaced 3 to 5 ins. apart. Hogs are very difficult animals to turn, and sheep will often get through a barbed wire fence that seems impassable. A special fence for holding hogs may have a bottom board, then two boards, and then two, three or four wires and a top board. The close (4-in.) spacing of the bottom wires of the Michigan Central Ry. fence is to prevent sheep and hogs from getting through. Where wires get slack, they may be connected by stays (between each pair or for the full height of the fence), or the slack may be wound upon a device looped to the main wire.

The wire fence in Fig. 72 has 16-ft. panels, with five lines of barbed wire,

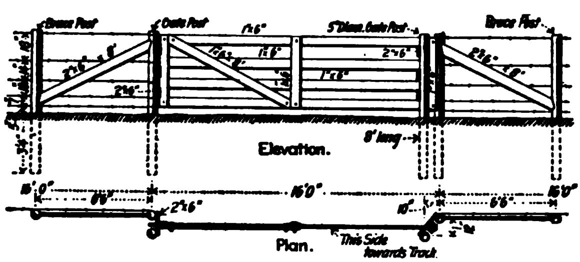


Fig. 72.—Wire Fence and Farm Gate.

spaced 5, 7, 10, 14 and 18 ins. The fence of the Canadian Pacific Ry., Fig. 73, has four barbed wires, a top board, and an inclined cap board. The posts are of round cedar, not less than 5 ins. diameter at the top, straight and peeled. The wire is stapled to the posts. The boards are nailed to each post with six 4-in. cut nails, and braces are put in at intervals of 300 ft., notched 1½ ins. into the posts and secured by 40-penny nails. Fig. 74 shows the styles of fence used by this road on rocky ground. The Atchison, Topeka & Santa Fé Ry. uses five wires on posts 16½ ft. apart, spaced as follows: 3 ins. (from ground), 10, 12, 12 and 14 ins. The hog fence has seven bottom wires (2½, 3, 3½, 4, 4½,

5 and 5½ ins. apart) with vertical stay wires 6 to 12 ins. apart; above these are two wires spaced 12 and 14 ins., without stays. The wire fence of the Louisville & Nashville Ry. has posts 7 ft. long, 10 ft. c. to c., with seven wires, spaced 4, 4, 6, 8, 10, 12 and 12 ins. The three lower wires are of barbed hog wire;

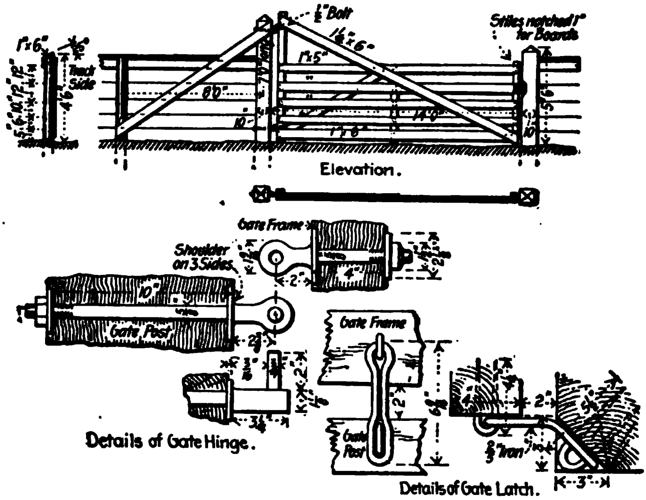


Fig. 73.—Wire Fence and Farm Gate; Canadian Pacific Ry.

the four upper wires are of barbed cattle wire, except that where there is danger to stock, the two top wires are plain ribbon wire. The Delaware, Lackawanna & Western Ry. has a fence 4½ ft. high, with 8-ft. panels. The posts are 7 ft long, not more than 8 ins. at bottom or less than 6 ins. at top. A top board 1×6 ins., 16 ft. long, is nailed against the face of the posts, and there are four

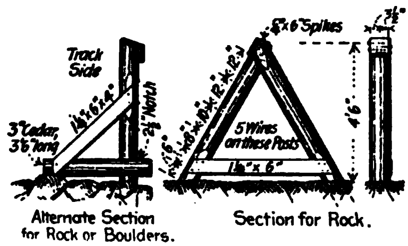


Fig. 74.—Fence Posts for Rocky Ground; Canadian Pacific Ry.

lines of two-strand No. 12 twisted wire. The bottom spacings are 6 and 8 ins.; the upper ones 11 ins.

Woven wire fencing is extensively used both for steam and electric railways. The old style, resembling poultry netting of large mesh, did not prove satisfactory. That now used is of heavier material, with longitudinal wires connected by vertical or diagonal stay wires. A special feature of many of these is that the longitudinal wires are coiled around a bar so that when straightened and made into the fence they retain sufficient bend and spring to take up expansion and contraction. The spacing of the longitudinal wires depends upon requirements, but is usually from 3 to 4 ins. at the bottom and 6 to 10 ins. at

the top. Vertical stay wires are usually 12 ins. apart, and are either wrapped around or tied to each longitudinal wire; they are usually continuous from top to bottom, but sometimes extend only from wire to wire. In one style, the longitudinal wires are given a bend or kink at intervals, instead of being coiled, and the stays are electrically welded to them. In several makes of woven fence, the stays are diagonal, and wrapped around each main wire. These are 6 to 12 ins. apart. The top and bottom wires are usually No. 7 or No. 9; other wires, No. 11 or No. 12; stay wire, No. 11 or No. 14. In some cases all the wires are of the same size. Fencing of this kind is delivered in rolls of from 20 to 40 rods, and the 54-in. railway fence weighs 10 to 12 lbs. per rod. For hog fencing a narrower width may be used, with horizontal wires above; and it is sometimes necessary to put a line of barbed wire above the top of the woven fence to prevent animals from leaning their heads over and bending down the top.

The right-of-way fence of the New York Central Ry. (Fig. 75) has 20-ft. panels. A 9½-ft. braced panel is put at corners, gates and angles, and at intervals of not more than 1,500 ft. in line fencing. Where the fence makes a flat angle, the post between the two braced panels is tied back by a wire attached to the top of the post and to an anchor set in the rear of the angle. The bottom wire is 1½ ins. from the ground, and the 11 wires are spaced 3 to 9 ins. apart, as in Fig. 75. The 6-in. posts are 8 ft. long, 3 ft. 2 ins. in the ground. The wires are No.

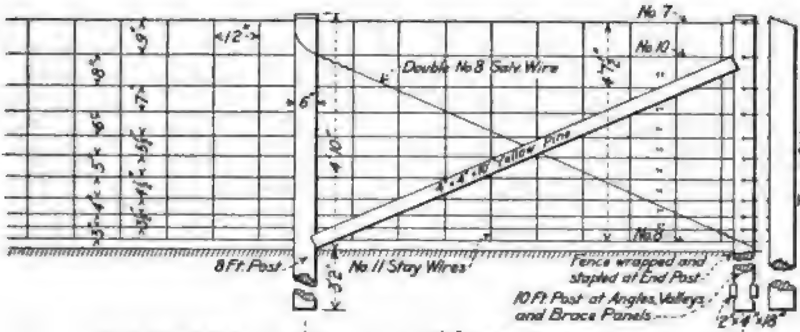


Fig. 75.—Woven-Wire Fence; New York Central Ry.

7 for the top, No. 8 for the bottom, No. 10 for other longitudinal wires, and No. 11 for the stay wires, which are 12 ins. apart. Some fences of this kind are built in the field, vertical stays of No. 7 hard steel corrugated wire, about 30 ins. apart, being secured to the longitudinal wires by special flexible clamps.

Considerable trouble has been experienced from the corrosion of wire fencing on steam railways, due to the acid fumes and gases from the locomotives. For this reason the wire is given a zinc coating. This is not by galvanizing but by passing the wire through a bath of molten zinc, the surface being smoothed and the excess removed by asbestos wipers. The speed of the wire should be such as to give it the same temperature as the bath, in order to get a coating that will adhere and not crack. An extra-heavy coating might be given by a slower speed, but it is said that this would be more liable to crack and flake when the wire is twisted or coiled in making the fence. It is not practicable to treat the finished fence, and such treatment would result in lumps at the intersections,

where the mètal could not be wiped. These would be liable to crack and fall off, leaving the wire bare.

Gates.—Fence gates are for openings 12 to 15 ft. wide in the clear; openings of 18 to 20 ft. may be necessary for harvesting machinery, and for such wide openings double gates may be used. The gate shown in Fig. 72 slides back for half of its length and then swings round, while some gates slide back for their whole length, parallel with the fence. An ordinary swinging gate is shown in Fig. 73, and this is well supported against drooping by means of the long brace. Iron-framed sliding and swinging gates are extensively used, some having a frame of steel angles or $1\frac{1}{4}$-in. gas pipe, with wires or netting attached to the frame. Gates should be strongly built and well hung on strong hinges. They may be so hung as to close by their own weight after having been opened, as farmers are frequently very careless about the gates. Even if made in this way there is a liability of their being propped open. A sheet-iron sign, marked "Close the Gate," may be attached to the gate. Trackwalkers should be on the lookout for open farm gates, and report any that may be habitually left open, as accidents have frequently been caused by cattle straying onto the track through an open gate, and in such cases a country jury may award damages to the farmer, in spite of the fact that the railway was properly fenced and the farmer himself was really responsible for the accident.

Walls and Hedges.—In districts where field stones and boulders are plentiful, dry rubble walls are sometimes built, but as a rule they are not very stable and soon get more or less broken down. Hedge fences are rarely seen in this country, and have the objection of taking up considerable space, and rendering an adjacent strip of field land useless on account of the shade, though they are sometimes considered desirable near cities for the sake of appearance. The Pennsylvania Ry. has tried hedges of osage orange. Hedges are sometimes used as snow breaks, as noted below. The Russian olive is very satisfactory and will survive heat, cold and drought; honey locust, barberry or California privet may also be used.

Station and Yard Fences.—Brick walls and ordinary or high board fences with vertical or horizontal boards placed close together are frequently used at station yards. A tight board fence may have 8-ft. posts 6×6 ins., or 8 ins. diameter, 6 or 8 ft. apart, with a cap board 2×6 ins., and two flat nailing planks 2×4 ins. mortised into the face. To these are nailed vertical planks $\frac{7}{8} \times 6$ ins., 6 or 8 ft. high, with a top board 1×4 ins. on the face. A line of barbed wire may be laid on the cap board. Picket fences or neat (and more or less ornamental) iron railings or fences are often used for the grounds at passenger stations, or to prevent persons from crossing the tracks, especially where there are separate tracks for through and local trains. A picket fence may have posts 5×7 ins., 7 to 10 ft. apart, with two flat rails 2×4 ins., or triangular rails (cut from a stick 4×4 ins.) let into notches in the posts. To these are nailed pickets, 1×3 ins., or 2×2 ins., with pointed tops, the pickets being $2\frac{1}{2}$ to 4 ins. apart and about 3 ins. above the ground. The Pennsylvania Ry. uses a fence between tracks at way stations, having pickets $1\frac{3}{8}$ ins. square, 4 ft. long, 6 ins. apart, on rails 3×3 ins.; the ends of the rails rest in iron sockets attached to the posts, so that the panels can be lifted out when track repairs are going on, or to allow room for attention to hot boxes, etc., on trains standing at the station. The posts are $4\frac{1}{2}$ ins. square, 10 ft. c. to c. A neat iron fence between the tracks or upon retaining walls may be 4 ft. high, with two rails of 2-in. channels or

bars $\frac{3}{8} \times 1\frac{1}{4}$ ins. 3 ft. apart, and pickets $\frac{1}{2}$-in. square, 5 ins. apart. All fences between tracks should have sliding or rolling gates for the use of employees, the gate having a spring lock, which is opened by a button or knob not readily found by the reckless passenger who tries to cross the tracks. Two designs of iron fence used in railway service are shown in Fig. 76. For ornamental grounds at stations, ribbon-wire or woven-wire fencing may be used, with steel angles or T-bar posts; the posts have back braces at intervals. Another plan is to use two lines of 2-in. gas pipe, 18 ins. apart, set in wooden or iron posts from 5 to 8 ft. apart. Hedges may also be used for such grounds.

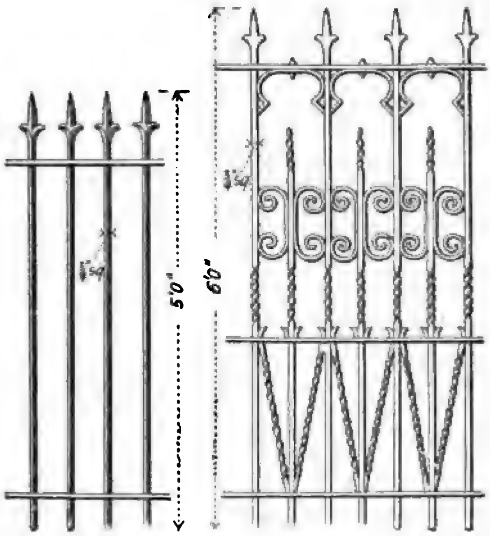


Fig. 76.—Iron Fencing for Stations.

Snow Fences.—The style of fence to be used on any road depends upon the topography and the amount of the snow. In prairie country these fences are of great importance, as that is often the most troublesome country in which to deal with drifting snow, especially if the track is raised but little above the normal surface. The fences may be either permanent or portable, the latter being made in sections which can be taken down when the winter is over. The permanent fence should be about 50 ft. from the track (or edge of cut) to allow for the drift, and may be from 6 to 8 ft. high, with eight or ten boards. If there is no room for this on the right of way, then the portable fence may be used, having the advantage that it can be set when needed, and that it does not permanently obstruct the view. The permanent fence shown in Fig. 77 is used by the Canadian Pacific Ry. at division yards, etc. Another style is shown in Fig. 78. Some of the fencing on the Northern Pacific Ry. is 9 ft. high, posts 8 ft. apart, with 8 boards 1×8 ins., and 6 ins. apart. There is also a considerable quantity of tight board fence, from 8 to 10 ft. high, which is found to be the most effective in heavy snow.

The movable fence in Fig. 79 is a good example of its type. The sections are 16 ft. long, and the braces and stakes are pivoted by carriage bolts, so that when taken up in the spring the panels can be folded flat and piled on the ground.

A similar fence on the Boston & Maine Ry. has the two posts intersecting and pivoted, with a cross-piece connecting their feet. The panels are set a panel

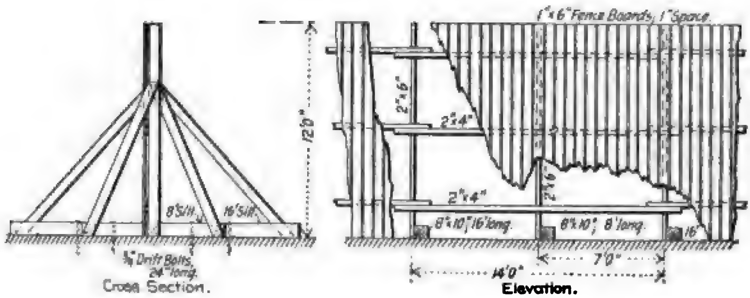


Fig. 77.—Permanent Snow Fence; Canadian Pacific Ry. (Winnipeg Yard).

length apart, the fence side facing the track, and the intermediate spaces are filled by loose panels made of planks nailed to two battens. These panels rest against the rear posts of the folding panels, and slope away from the track.

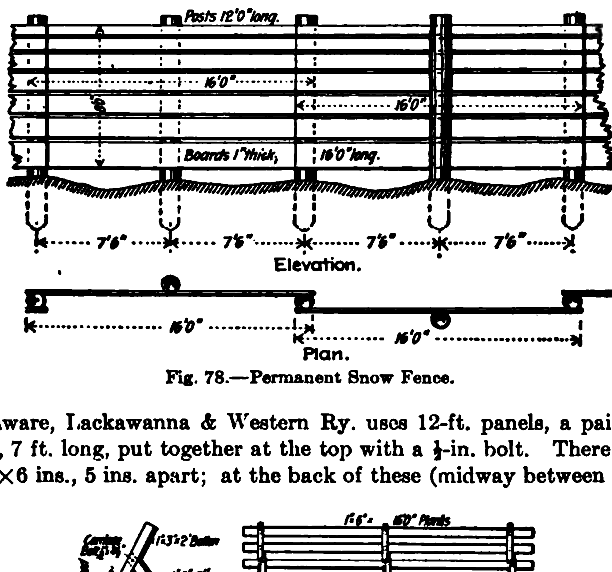


Fig. 78.—Permanent Snow Fence.

The Delaware, Lackawanna & Western Ry. uses 12-ft. panels, a pair of posts 3×4 ins., 7 ft. long, put together at the top with a ½-in. bolt. There are seven boards 1×6 ins., 5 ins. apart; at the back of these (midway between the posts)

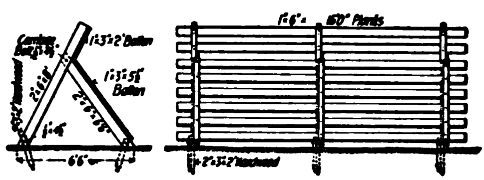


Fig. 79.—Portable Snow Fence.

is a batten 1×6 ins. The New York Central Ry. puts open portable fences about 80 ft. from center of track, and tight board fences 10 ft. distant for each foot of height. In extreme conditions, two lines of fence are set 100 ft. apart. At shallow cuts, the fences may be nearer the track, but the minimum distance

from top of cut is 50 ft. for open fences and 40 ft. for 7-ft. tight fences. The fence is parallel with the track, but at each end is 100 ft. of flanking fence reaching to about 40 ft. from the center of the track. This road recommends hedges as permanent protection where tight board fences must be used on account of inability to occupy the adjacent land.

The snow fences should extend beyond the ends of cuts and then flare in gradually towards the track, so as to protect the cut from drifts caused by winds blowing at an angle to as well as directly across it. If they are not extended far enough, an oblique drift may be formed and cause a derailment. The New York Central Ry. practice in this respect is noted above. On one part of the Boston & Maine Ry. permanent snow fences are built down the slopes of the cuts, about 90 ft. apart, alternating on opposite sides of the cut, and placed at right angles to the direction of the prevailing winds which tend to fill the cuts with snow. They serve admirably to prevent snow from drifting across the tracks, but the portable fences would answer the purpose equally well and be less objectionable in appearance. In Scotland and Germany some use has been made of fences so placed along the windward side of the cut as to deflect the wind downward into the cut and so keep the snow scoured out. The fence panels or deflectors are pivoted between posts set in the slope of the cut, and are adjusted to the proper angle, the upper edge being above the top of the cut.

If the movable fence is used as an auxiliary to a permanent fence it may be placed 100 ft. beyond the latter, or where required to break the force of the drifting snow, the eddy formed by the wind causing the snow to be deposited on the field side, as in Fig. 80, while beyond is the secondary drift. Landowners may demand a small rental for the right to put up this fence in the winter. When the first drift is as high as the fence the snow will blow over, and the fence may then be placed on top of the drift. If it becomes buried in the snow, a wall may be built of blocks of snow, wide enough for stability and 6 or 8 ft. high. Such work is very hard, and should be avoided, as it must generally be done during severe cold and often in a high wind with driving snow. It is a good plan to widen the cuts with very flat slopes, using the material excavated to form permanent snow banks or fences a little distance from the edges of the cuts. Rows of small balsam, cedar or small evergreen trees, 8 ft. apart, staggered in two rows, the nearest row being 100 ft. from the track, make good snow fences or snow breaks, but their use is not generally practicable. Certain bushes make good snow hedges, as already noted.

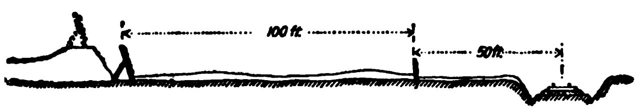


Fig. 80.—Position of Permanent and Portable Snow Fences.

Wing Fences.—To shut off the right of way between the track and the boundary fence at road crossings, a wing fence is built from the middle or end of the cattleguard to the right-of-way fence. This usually carries a rectangular or triangular panel of apron fence parallel with the track, as shown in Figs. 81 and 82. The ditch may be closed against small animals by stakes driven into the ground and nailed to the bottom of the wing fence. The width between the aprons at rail level is generally 10 ft. and they should be inclined away from

the track, so as to be clear of persons on car steps or freight-car ladders. In districts where there is much snow, the aprons and the ends of the wing fences are sometimes removed in winter, so as not to foul snow plows. The wing and apron fences should be kept well whitewashed, as cattle object to passing a whitewashed fence more than an ordinary fence.

Cattleguards.

Where highways are crossed at grade, a cattleguard is usually placed across the track at each side of the road, with wing or lateral fences extending to the main fences, to prevent cattle from straying onto the track or right of way. They are also used to some extent at the approaches to bridges, tunnels or deep cuts. The cattleguard is placed some distance from the bridge, and the fence

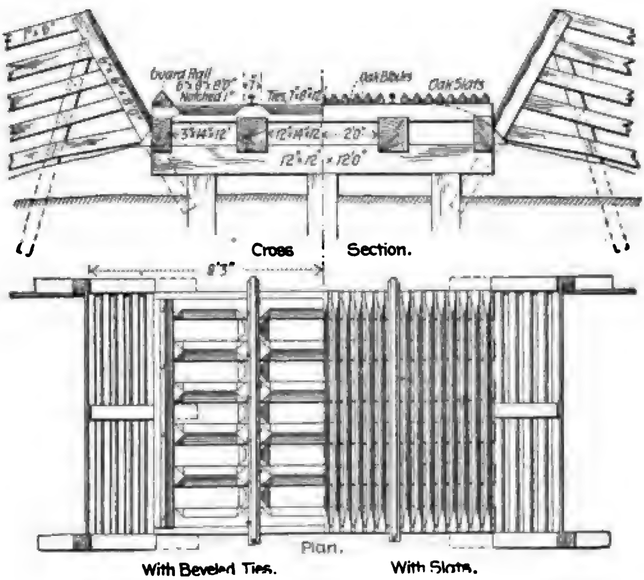


Fig. 81.—Pit Cattleguard.

is carried along on each side to the abutments or under the first span. At tunnels, the cattleguard is placed near the mouth of the approach cut, and the fence is carried along the cut and over the portal. For deep and narrow cuts the cattleguard is placed near the mouth of the cut. Besides being effective in turning cattle, the guard should meet the following requirements: 1, Reasonable in first cost and maintenance expense; 2, Permit of proper maintenance of track; 3, Not liable to cause derailment or wreck a derailed train; 4, Not liable to become loose or to be caught by low-hung brake rigging, etc.; 5, Easily and safely passed by employees; 6, Not liable to trap or throw cattle attempting to pass; 7, Not noisy or rattling under trains.

It is not as easy to turn cattle as might be supposed. If straying along the road they will sometimes spend considerable time in trying the guards, either from a desire to wander or to reach some tempting feed. Some cattle are inveterate wanderers, and will cross almost any form of guard, even as others are inveterate fence breakers or jumpers. If being driven they will often either

run blindly into or over the guard, and the length of the guard should be sufficient to deter them from jumping. Ordinary farm cattle rarely give much trouble (with the exceptions noted), but range cattle are very hard to turn. Hogs and sheep are persistent in attempts to reach forbidden ground. If cattle are standing up when struck by a train there is a good probability of their being thrown clear of the track, but if they are lying down a derailment is almost inevitable. The killing of cattle is a troublesome feature (especially in the West, where so much land is unfenced), both on account of the liability of injury to trains and passengers, and the amounts involved in paying for cattle (the value of the animals being usually put at a maximum). It does not seem reasonable, however, to hold the railway company alone responsible for the killing of cattle, as is usually the case, and not to hold the owner responsible for not fencing his land or for allowing his cattle to stray in such a way as to endanger the safety of railway passengers. The trains have a right on

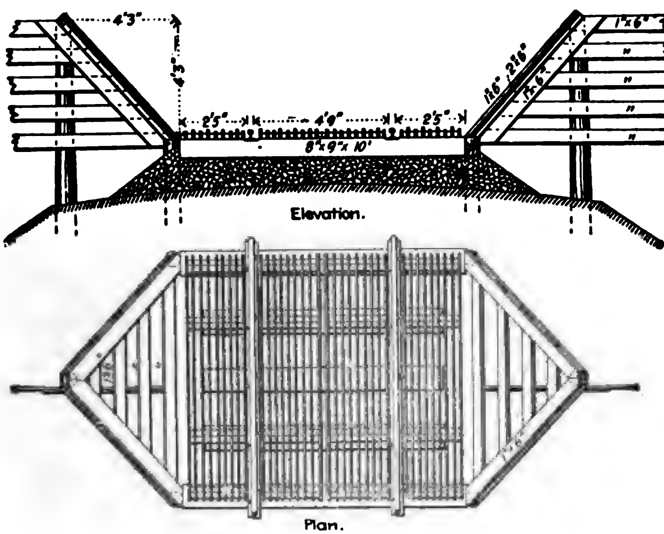


Fig. 82.—Metal Surface Cattleguard; Pennsylvania Lines.

the track, but trespassers and cattle have no right, and this should be recognized. The laws of some States prohibit the turning of cattle loose on the highways.

The guards are ordinarily placed with the road ends in line with the road fences, but a Canadian commission recommended that they should be set in the waste strip for each side of country roads, with a section of fence on each side of the guard (parallel with the rails). In this way, the fence would compel wandering cattle to turn towards the road, where they would be likely to walk past the narrow opening, especially as the full length of the guard then separates them from the right of way. Cattleguards may be divided into two general types, pit and surface. The former has a number of disadvantages, and the latter is now most generally used.

Pit Cattleguards.—The pit guard consists of an excavation in the roadbed, the full width between wing fences, or about 12 ft. wide in the clear, from 5

to 10 ft. long (lengthwise of the track), and from 30 to 36 ins. deep below base of rail. The pit is often entirely walled up with timber or masonry, but the ends should be left open to provide for drainage. The rails are carried across the pit upon stringers, leaving an open pit; or upon cross-ties laid upon the stringers. If ordinary ties are used, they may be covered with longitudinal wooden slats, as shown in Fig. 81. It is more usual, however, to have the edges of the ties beveled (except at the rail seats) for about 4 ins. in depth, or they may be laid diagonally in V. notches on the stringers, rail seats being formed in the upper edge. While both arrangements afford but an insecure footing to cattle attempting to cross, they have the objection of being liable to cause the animal to slip through while trying the guard, so that it could not escape and might easily cause the wreck of a train. In case of a derailed wheel or truck reaching the guard, the beveled ties would afford little greater security than the open pit. The pit also makes a bad riding place in the track, by breaking up the continuity of the roadbed, and its walls are liable to be heaved by frost. The timbers are also likely to catch fire, to rot, or to settle; and the pit forms a receptacle for dirt, refuse and moisture.

Surface Cattleguards.—These have largely superseded the pit guard, since they are free from danger to trains, and (if properly constructed) should be as efficient in turning cattle. The simplest form consists of wooden slats from 5 to 8 ft. long, and of triangular section, made from 3½-in. or 4-in. pine sticks cut diagonally and laid parallel with the rails. They should not be nailed to the ties, but bolted together (with spacing blocks between). One or two of such sections are placed between the rails, and two are placed outside the rails. Other sections are placed between the tracks on a double-track line, being supported by planks or ties. The construction is similar to that in Fig. 81, the slats being about 10 ft. long, 4 ins. deep, ½-in. wide on top, and 2 ins. on the bottom, the lower 2 ins. of the sides being vertical, so as to fit the spacing blocks, 2×2 ins., and 8 ins. long, placed between the slats at the ends and middle. The parts are held together by three ¾-in. rods passing through the slats and spacing blocks. In some cases a strip of barbed or twisted wire is nailed along the top of each slat, but this is liable to get loose. Surface cattleguards with wooden slats are standard on many roads, and the usual length is 8 ft., though 10 or 12 ft. would be better. On the Baltimore & Ohio Ry. the slats are 8 ft. long, made by cutting a stick 6×2½ ins. diagonally at 1¾ ins. from each end; this gives a 2½-in. base, and sides 1¾ and 4¼ ins. high. A triangular end panel on the wing fence carries an inclined triangular apron fence; the bottom of this is 18 ins. from the rail and the top 9 ft. 4 ins. from center of track. On the Delaware, Lackawanna & Western Ry. the slats are also 8 ft. long, but rectangular, 2¼ ins. wide, 2½ ins. high and 2½ ins. apart. They are held together by three ¾-in. transverse rods, with spacing sleeves of 1-in. gas pipe. Tho ends are beveled. On top of each slat is an iron strap having the edges notched and bent up to form barbs. The inclined triangular apron fence rests on short posts. A 1-in. plank is laid on each tie, to carry the cattleguard, and on double track the two end ties are connected by planks to carry the intermediate section of the guard. The Climax guard, which is used by a number of steam and electric roads, consists of blocks of vitrified clay forming triangular ridges parallel with the rails. Each block is 24 ins. long, 8½ ins. wide (with two ridges) and 4 ins high, weighing 33 lbs. They are laid on five ties spaced 2 ft. c. to c. and are secured by cross strips nailed to the end ties.

Metal surface guards are also extensively used. The majority consist of a series of slats of steel angles, tees or flat bars parallel with the rails, and forming an insecure footing. One used on the Pennsylvania Lines is shown in Fig 82. The slats are inverted T-bars supported in triangular iron cross-pieces, and are set alternately high and low. In some cases flat bars set on edge have wavy or saw-tooth top edges, and sometimes barbs on the sides, so as to cause pain to any animal making a determined effort to cross. Flat plates sometimes

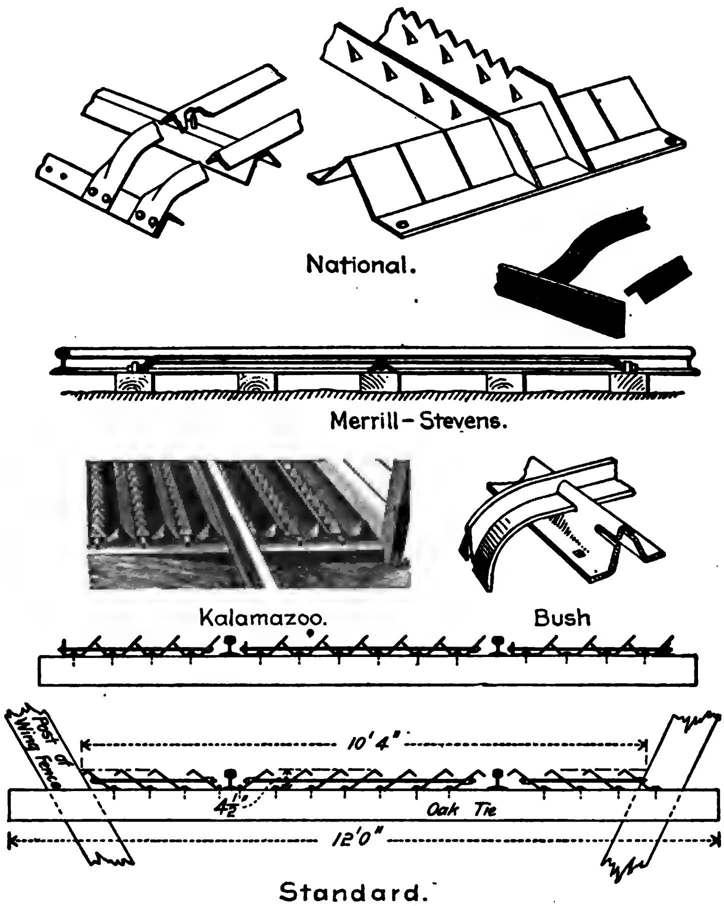


Fig. 83.—Metal Cattleguards.

have teeth punched up out of the metal for the same purpose. While the teeth and barbs may add to the effectiveness of the guard in turning hogs and small stock, they are open to the objection of possibly causing injury to stock, for which the railway company may be held liable. They may also cause injury to flagmen and others walking on the track. Metal guards which have a flat bottom plate covering the ties and ballast have disadvantages over the slat forms in being liable to cause rotting of the ties by holding water between the plate and tie, while the heat of the plate in summer also aids in this effect.

Some metal surface guards are shown in Fig. 83. The Kalamazoo guard has triangular ridges, and triangular teeth punched up out of the flat strips of plate between the ridges, so that an animal's hoof will slip down upon the teeth. The ridges, being higher than the teeth, would protect a person falling on the guard. This guard, 9 ft. long, weighs about 375 lbs. The National guard has slats of T or Λ section attached to cross-pieces, alternate slats being 1½ ins. above the others. Another form has flat plates, 2½ and 3½ ins. high, 2¾ ins. apart, set on edge in the transverse pieces. The Columbian guard has steel angles 1½×1½ ins., laid to form Λ-shaped slats; this weighs 320 lbs. for a length

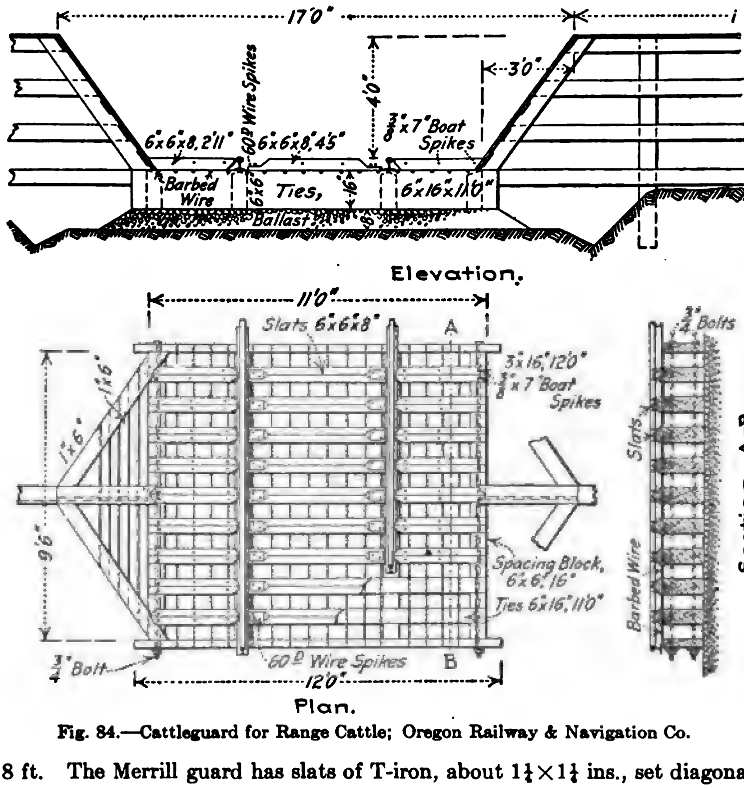


Fig. 84.—Cattleguard for Range Cattle; Oregon Railway & Navigation Co.

of 8 ft. The Merrill guard has slats of T-iron, about 1¼×1¼ ins., set diagonally in the end cross-pieces, and made level with the rail head; the space beneath the guard and the insecure footing of the slanting bars tend to check cattle. The Standard guard has flat or Z-shaped plates, parallel with and inclined towards the rails. The Bush guard has slats of inverted T-irons, 2 ins. apart, carried in slotted cross-pieces of pressed steel, the bars being at different heights; this guard weighs about 450 lbs. In the Climax guard, no slats are used, but a Λ-shaped strip of expanded metal is placed upon each tie, with its edges projecting beyond the tie, so as to strike the leg of an animal trying to set a footing between the ties. With this arrangement there is no interference with the ordinary work of lining, surfacing and ballasting, while slat guards must be removed for this work.

The difficulty of turning range cattle has already been mentioned, and the Kennedy cattleguard used as standard for this purpose by the Oregon Ry. & Navigation Co. is shown in Fig. 84. Cross timbers 6×16 ins., 11 ft. long, are set on edge, and bolted together with 6-in. spacing blocks at the ends and under the rails. Strips of barbed wire are laid parallel with the rails and secured by triangular sticks nailed upon the ties. No ballast is filled between the ties. This form of cattleguard is also the standard of the Western Pacific Ry.; in this case, however, the ties are 8×12 ins., 10 ft. long and 8 ins. apart. The wider spacing affords less chance of a horse's foot being caught, 8 ins. being about the size of the largest horseshoe. The wider spacing and reduced depth also facilitate tamping the ties. No through bolts are used. In any slat or open guard, the removal of ballast from between the ties adds to the efficiency, spacing blocks being used to give the necessary support. Among the various designs for surface guards there are some in which the animals are compelled to step on planks between the ties, which planks are loose, and are connected to a transverse rod carrying several prongs 18 to 24 ins. long, forming a fence which rises in front of the animal, but lies normally flat on the ties.

CHAPTER 9.—GRADE CROSSINGS.

Highway Grade Crossings.

The avoidance of grade crossings at highways has within recent years become a consideration in railway location in the settled portions of the country, while existing crossings are being eliminated, to the benefit of the railways and the public. In too many cases, railways still run through towns and cities on the street grade; they either have their own right of way and merely cross the streets, or else run along the middle or side of a street. In such cases it is very difficult to keep the track in good condition. In many cities steps have been taken to eliminate the grade crossings; the railways are either depressed and laid in an open cut with retaining walls, and crossed by bridges; or raised on a viaduct or bank, crossing the streets by bridges. Street grades are very frequently changed at the same time so as not to require the tracks to be raised higher than necessary. Such work is often very difficult and almost invariably very expensive, involving a large amount of railway and municipal work. The work must be done during traffic, which is an unfavorable condition for economy. The railway, however, is then free from the expenses incident to gates, watchmen, accidents, etc., and from the delays caused by crossings, so that it can operate its traffic to better advantage. There are also many cases where country road crossings can be eliminated to advantage, especially in improving the grade for the railway. In New York State, the law prohibits new railway and highway construction involving grade crossings. Where a new railway crosses a highway, the expense of avoiding a grade crossing must be borne by the railway. Where a new highway crosses a railway, the cost is divided equally between the railway and the municipality. In the elimination of existing crossings the cost is distributed as follows: 50% by the railway, 25% by the municipality and 25% by the State. Similar laws exist in Massachusetts and other States.

Country Roads.—Country road crossings are usually either planked all the way across or have planks on each side of the rails with gravel or cinder filling between. The planks are 3 or 4 ins. thick, from 12 to 16 ft. long for farm crossings and side roads, or up to 30 ft. for main roads. Five 10-in. or four 12-in. planks will fill in neatly between the rails, while a similar plank will be laid outside of each rail. If the rails are high, the planks rest on strips nailed to the ties, so as to bring the planks flush with the top of the rails or ½-in. below. The ends of the planks are adzed to an incline for 6 to 12 ins., so as not to catch loose hanging rods, chains or brakebeams. Pine planks are more suitable than spruce or oak; the second are too soft and the third have a tendency to warp. They should be spiked by ⅜-in. boat spikes 8 to 10 ins. long, track spikes being too short. If planks are laid only against the rails, cross planks may be laid between their ends, forming a shallow box to be filled in with broken stone or gravel for roads, or gravel or cinders for private and farm crossings. Where track is liable to heave, the planks may be removed from unimportant crossings in the winter, so as not to be struck by engine pilots or snow plows. At narrow crossings the planks should, if possible, be placed so as not to cover any rail joints. It is difficult to properly inspect and repair such joints, and in some cases 60-ft. rails are used to bring the joints beyond the crossings.

The outer planks are laid close against the rail heads, but the inner ones must leave flangeways about 2½ ins. wide. These planks may be set that distance from the rail, or their edges may be rabbeted to fit under the rail heads, leaving flangeways 2½ ins. wide and the full depth of the rail head. A shallow flangeway has the objection of being more easily obstructed by loose stones, etc., but if the space is left open for the full depth of the rail, horses are liable to get the calks of their shoes caught under the rail head. It is generally best, therefore, to put a filler against the web at any rate. A steel rail is frequently placed as an inside guard rail to form the flangeway and protect the edges of the planking or the gravel filling. This is generally laid on its side, with its head resting against the web of the track rail, thus forming a shallow flangeway with filler. If placed upright or laid on its side with its base toward the track rail, broken-stone filling or a wooden filler strip should be placed between the rails as already noted. In the latter arrangement (rarely used) a plank must be cut to shape to rest upon the guard rail, being secured by long spikes driven through holes in the plank and rail web. The ends of the guard rails should be flared out from 6 to 12 ins. at the ends, giving a clearance of at least 4 ins.; this space should be filled with some form of footguard. Several arrangements are shown in Fig. 85.

The approaches to the crossings should be properly built and graded, and may be carried across the roadway ditches by planks spiked to timbers or old ties, resting on the bank and the roadbed, but these timbers are liable to rot and easily become loose, making an unsightly crossing. It is generally better to carry the ditch through by an iron pipe 8 to 12 ins. diameter, and then to fill in the earth to make a properly graded approach. Clay pipe is likely to be broken or displaced unless the earth cover over it is pretty thick, while a wooden box drain is likely to break or decay and allow the earth to fall in and block the drain. The ends of the pipe or drain may be laid in small dry walls and covered by screens. These pipes should be of ample capacity, and should be cleaned out occasionally. Signal wires may be laid through an iron pipe; or electric wires may be protected by being laid in a 1-in. pipe with end caps and gaskets

(having holes for the wires); the pipe to be filled with oil. These pipes are supported on stakes. Crossings and approaches should be well drained and always kept in good repair, not only on account of the safety of railway and highway traffic, but also because defective and unsightly crossings are a frequent cause of public complaint, leading to an ill feeling against the railway.

Streets.—Where the tracks run along or across paved streets, an iron guard rail is generally placed inside the track rail, and the paving filled in over the ties, leaving only a flangeway, which should have a filling piece up to the level of the under side of the rail heads. In some cases a line of planking is laid along the outside of the rail head. For freight tracks in Philadelphia, the Pennsylvania Ry. uses a 141-lb. grooved girder rail 9 ins. high with a 6-in. base. The groove is 1¾ ins. deep; the width of head is 2$\frac{7}{32}$ ins., and the flaring guard is $\frac{5}{16}$-in. thick; the width from head to outside of guard is 2$\frac{19}{32}$ ins. The joints have flat narrow-flanged splice bars (with an inner rib bearing against the rail

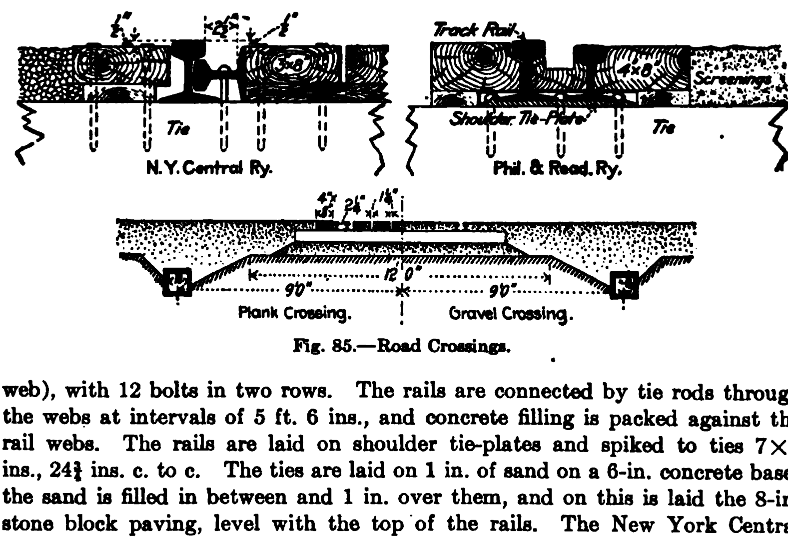


Fig. 85.—Road Crossings.

web), with 12 bolts in two rows. The rails are connected by tie rods through the webs at intervals of 5 ft. 6 ins., and concrete filling is packed against the rail webs. The rails are laid on shoulder tie-plates and spiked to ties 7×9 ins., 24¾ ins. c. to c. The ties are laid on 1 in. of sand on a 6-in. concrete base; the sand is filled in between and 1 in. over them, and on this is laid the 8-in. stone block paving, level with the top of the rails. The New York Central Ry. uses chairs to carry ordinary track rails. The ties are 3 ins. below the normal level, laid on 6 ins. of gravel ballast, with 6 ins. of concrete between them and extending to the sides of the street. Upon each tie are spiked two iron chairs, 3 ins. high, with a base 9¾×4 ins., and weighing 20 lbs. each (25 lbs. at joints). The rail seat has a shoulder along each side, and the rails are secured by semicircular steel spring clamps which are driven on parallel with the rail and grip the rail flange and top of chair. To the inside of each rail is bolted a continuous angle-bar of special section, with a broad upper flange about 2 ins. wide. This built-up section resembles a side-bearing street rail, the depth of flangeway being the full depth of the rail head. The bolts are 4 ft. 4½ ins. c. to c., and at the rail joints a 36-in. length of the guard angle or bar is used, with an outer six-bolt angle splice bar. The clamps on the three joint chairs grip the flange of this latter splice bar. The track and guard rails break joint about 18 ins. Over the concrete and ties is a 2-in. layer of sand, upon which are the paving blocks; those on the outside are ⅝-in. below the top of the rail, while those on the inside are level with the flange of the guard rail. In

brick paving, the rails are laid on steel plates of such thickness as to give 6 ins. from tie to top of rail. On a 2-in. bed of sand is laid the 4-in. brick paving, grouted with pitch. A rail laid on its side forms the flangeway, and a round-nosed brick is laid against this.

Road-Crossing Signals and Gates.—Country road crossings are generally protected only by warning signs, though flagmen or automatic gongs are also sometimes employed. At suburban crossings of busy lines, signs and gates are very generally used (or flagmen instead of gatemen). These are often supplemented by automatic gong signals, having either a large gong to warn persons approaching the railway, or a small gong to warn the watchman to flag the highway traffic or to close the gates. Lamps may be operated in connection with the large gong, but this is rarely done, except on electric lines. For these automatic warning signals, the train usually closes an electric circuit when 600 to 2,000 ft. distant, and the gong continues to ring until the train has passed the crossing. Unreliable appliances are dangerous, as a silent gong indicates a safe crossing, and persons who have once found the gong inoperative are likely to disregard it in the future. Some of these signals, however, are reliable within all reasonable requirements (including proper attention). In this connection it is pertinent to call attention to the folly of employing incompetent men at low wages as flagmen or gatemen at crossings. Such men will not and do not attend faithfully to their duties and many accidents have resulted from their carelessness.

Ordinary street crossings have usually gates operated by watchmen. In rare cases "portcullis" gates are used, sliding vertically in high frames, while an arrangement has been suggested by which the gates would drop into deep narrow slots in the street. The most common form of crossing gate is a light wooden arm, swinging vertically and pivoted to an iron post near the curb, and being operated by gearing by means of a crank handle in the post. The sidewalk arms are operated by segmental racks on the shafts. The arms on both sides of the track are worked together, the connections being wires, chains, or pipes led underground with bell-crank connections. The arms are counterbalanced. They are sometimes as much as 55 ft. long, with 35-ft. sidewalk arms, where the tracks cross the street at an angle, but it is common to use two arms on each side of the track. These gates are about 9 or 10 ft. from center of track. The gateman usually has a small cabin at the side of the track, or an elevated cabin like a signal tower. Gates of this kind may have a flexible piece at the end, opening upward and outward, so that if a team is shut in on the track it may be driven through, and thus perhaps avoid a serious accident. A flag or target may be placed on the gate, while at night a green or white lantern is hung upon it. The Philadelphia & Reading Ry., however, puts a green flag by day, while at night there is a lamp showing red to the highway and green to the railway. The gates are sometimes operated by wires, chains or pipe lines, connected to levers. More generally they are operated by compressed air, one or two strokes of the lever of a pump in the tower effecting each movement of the gate. A pressure of only 7 lbs. per sq. in. is required. The operating mechanisms for the arms are enclosed in the gate posts, which are connected by ½-in. pipes, and the arms are locked in either position. One design uses a rubber diaphragm in an iron case; others use a piston in a cylinder. One stroke of the pump operates the arm or arms on one side of the track, thus requiring two strokes to close the crossing and so reducing the liability

to shut a team in on the track. One diaphragm of each pair closes the gates, and the other opens them, motion being transmitted by a rod, chain and bell cranks in each post, connected by rods underground. Automatic gates are not advisable, being likely to trap horses or vehicles.

Street crossings at yards and stations, where trains and switch engines are constantly moving to and fro, are often protected only by flagmen, who signal the drivers of vehicles when to cross. If there are many tracks, an open refuge place should be provided near the middle, so that teams need not wait until the entire crossing is clear. Such crossings, however, are extremely dangerous, especially in dark and stormy weather, when the drivers cannot see the flagmen distinctly, and the flagman's view is obstructed by smoke and steam. At street crossings having tracks for electric cars, there should be provided some means of automatically stopping or derailing these cars if they run past a certain point when the gates are closed, as many accidents occur through carelessness or neglect on the part of car drivers, conductors and gatemen. The ordinary rule is that the car must be stopped and the conductor walk onto the crossing to see if trains are approaching; but he may be neglectful, or his view may be obstructed by steam, smoke or moving cars. Derails or stop blocks, about 50 or 100 ft. from the crossing and interlocked with the gate, should be set in the street track, and for electric railways the current may be automatically cut off from the trolley wire for a short distance on each side of the crossing. This matter is further discussed in connection with railway grade crossings.

Railway Grade Crossings.

Railway crossings at grade were freely adopted in earlier days, but it is now generally recognized that every such crossing is a point of danger and expense, causing more or less interference with traffic and increase in maintenance work. At unprotected crossings, where all trains are required to come to an absolute stop, there is likely to be increased wear of rails due to the frequent stopping and starting and the use of sand. The extent of the wear will vary with the local conditions of grade, speed, traffic, etc. The expenses due to the delays at crossings are discussed in the Proceedings of the Railway Signal Association, 1905. In many cases these crossings can be avoided or eliminated with advantage to both roads (sometimes with an improvement in grades), and there is a growing tendency to protect crossings by interlocking switch and signal plants, so that a train will not have to stop unless the right of way has already been given to a train on the other line. In some States this protection is compulsory. There is also a general tendency to eliminate groups of crossings near large cities, and enormous sums of money have been expended in the separation of grades, which expenditures have been fully warranted by the increased safety and freedom of traffic. Near Philadelphia, the four tracks of the New York and Philadelphia divisions of the Pennsylvania Ry. connected with the line leading to the Broad St. terminal station in such a way that all passenger trains for that station had to cross the through main tracks, causing numerous delays, and also causing complication in handling the enormous number of freight trains at that point. This has been avoided by lowering the tracks of the New York Division on a grade of 0.5% until they can pass under the freight yard at 1%, and then rising again by a grade of 1.2% to the normal grade. The crossing of trains at junctions, especially on four-track lines, has also been avoided in some cases by carrying one track over or under the normal grade.

Two arrangements of this kind are shown in Fig. 86. Such improvements not only facilitate the traffic and insure safety, but also reduce the expenses for maintaining crossings, switches, derails, interlocking plant, etc.

In the building of new railways there should be some legislative restriction upon the right to cross existing railways at grade, thereby interfering with the traffic of the latter and conferring upon them no corresponding benefit. The permission of the Railway Commissioners (or similar authority) should be required in each and every case, and should be granted only when the impracticability of separating the grades (or other good reason) can be proved. Unprotected crossings should be permitted only in exceptional cases, and the new railway might well be required to pay the entire cost of the construction and equipment of the crossing, including signals, interlocking plant, etc., subject to the approval of the existing line; and to pay also the expenses of watchmen, signalmen, and maintenance of plant. With such requirements, greater care

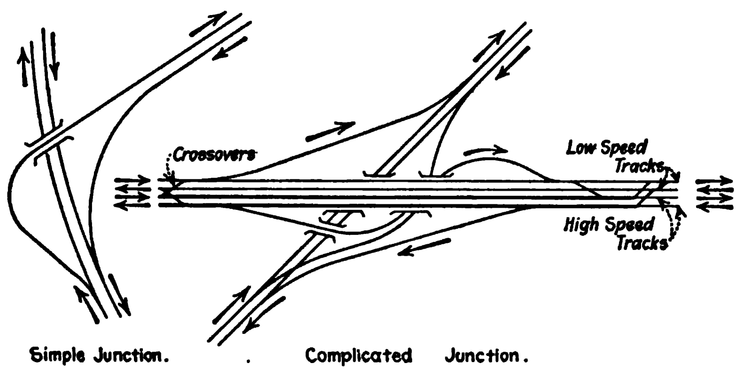


Fig. 86.—Avoidance of Track Crossings at Junctions.

would be taken to avoid such crossings, and there are comparatively few cases where they could not be economically avoided, especially if the continued expense for their operation and maintenance is taken into account. In some States (including New York, New Hampshire, Massachusetts, Indiana, Ohio and Illinois), there are laws in regard to the avoidance and protection of grade crossings, including those of electric and steam railways as well as of steam railways alone.

All important crossings should be equipped with interlocking plants, with home and distant signals and derailing switches, but local conditions must govern the application of these switches, as in some cases they may be dangerous. Every interlocking plant should have both home and distant signals. If an engineman finds the distant signal clear he knows he has the right of way over the crossing, but if he finds it against him he slows down and runs under control, expecting to be stopped by the home signal. The derailing switch should be not less than 300 ft. from the crossing on level track, and in Illinois the distance is required to be at least 400 ft., on account of the increase in weight and speed of trains. On a double-track line there should be a "backup" derail, 150 to 300 ft. beyond the crossing. The home signal may be 150 to 200 ft. from the crossing, and the distant signal 1,200 to 2,000 ft. from the home signal. The location of the signal and derails will depend upon the speed of trains, grades,

etc., but the distant signal should be so far back as to give room for a fast train to be stopped before reaching the home signal, while the derail should be just beyond the home signal, but so far back that a derailed train will not be likely to reach the crossing. The derail may open to a short curved spur ending in a sand bank, so as to turn the train away from the crossing. It should be distinctly understood by all enginemen that the towerman is the man in authority at the crossing and can give the right of way to which train he pleases (subject to the general instructions given him), and the engineman has simply to look out for the signals and obey them implicitly. The signals are normally at "stop," and an approaching train whistles to notify the towerman. He may not hear this at once, or may be unable to determine upon which line the train is approaching, and delay in clearing the signals may result in checking a fast train unnecessarily. To prevent this, a relay may be put in at any desired distance, so that as the train passes it automatically operates a bell, buzzer or indicator in the tower.

Crossings of small country lines with little traffic are often left entirely unprotected, except by "slow boards" or signs. If near a station, there may be a gate or horizontal bar swinging around a vertical post, and having a target or lamp on it; one or other of the tracks being always blocked. Lifting gates, as used at road crossings, are also used in some cases, being so interlocked that only one road can be cleared at a time. The protection of crossings of steam and electric railways is discussed below. A simple interlocking system for grade crossings of main lines by smaller lines or electric railways, consists in equipping the less important track with derailing switches standing normally open, these derails being interlocked with the signals of the other line. In one system of this kind, when a train on the principal line reaches a point half a mile ahead of the automatic signal governing the block in which the crossing is located, it causes an indicator to be displayed at the derailing switches, giving warning of the approach of a train having the right of way. If a train on the smaller line finds that no main-track train is approaching, the trainman closes the derailing switch, and thereby sets the main-track block signals at danger. (See also Chapter 14.)

Electric Railway Crossings.—The increased weight and speed of electric cars, and the numerous accidents and narrow escapes at crossings, have made it evident that the grade crossing of a steam railway and an electric railway should be as efficiently protected as a crossing of two steam railways, and should be under the same State regulations. This is specially important in view of the great development of electric interurban railways, on which cars run at high speeds, and the action taken by some States is much to be commended in putting a check upon this multiplication of dangerous grade crossings. They may require over or under crossings to be made, or at least put facilities in the way of providing such a separation of grades by permitting the condemnation and purchase of land for the diversion of an electric railway to avoid a grade crossing. The electric railway, as responsible for the crossing, may also be required to put in an interlocking plant approved by the Railway Commission and the steam railway, and also to pay a large proportion of the expense of operation and maintenance. Grade crossings of this kind call for more careful watching than grade crossings of steam railways and are really more dangerous, as the steam road claims the right of way, and the movement of cars on an electric road is liable to derangement without notice or apparent cause. Cases are numerous

in which electric cars have in some way been deprived of power while passing over grade crossings. Interlocking plants may be used, it is true, but cannot insure absolute safety, while they involve continual expense for maintenance. Their use may in some cases be almost impracticable, as when the electric line crosses a high-speed line, switching tracks or a yard. In the construction of some electric railways intended for high-speed service, considerable expenditures have been incurred in building diversions or viaducts purposely to avoid crossing steam railways at grade.

This applies to street-railway lines, as well as to suburban and interurban lines. At a double-track crossing of the Pennsylvania Ry. and an electric line at Newark, N. J., a derailing switch (to both rails) is put in the electric track at about 80 ft. from the steam tracks and another derail beyond the latter. These are connected, and are normally open. The conductor must get off and close the derail by a lever placed near the steam tracks and must hold the lever until the car has crossed the derail on the opposite side of the crossing, as a spring will open the derail as soon as the lever is released. This plan has the objection

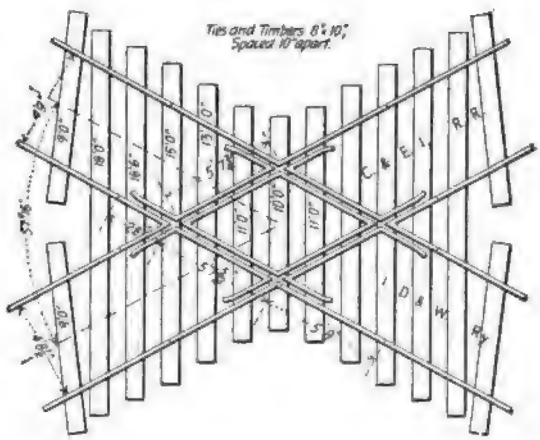


Fig. 87.—Track Crossing Laid on Ties and Long Timbers.

that the conductor is away from the car at the critical moment when the trolley is liable to leave the wire and stall the car on the crossing. There are, however, devices in the form of a trough over the trolley wire (extending 50 to 75 ft. beyond the crossing), which are electrically connected with the wire; thus the trough would not only catch the trolley but supply it with current. The lever of the derailing switches might have an electric lock to automatically prevent its being operated when an approaching train is within a certain distance. This could not be used at those dangerous crossings in or near cities where switching movements foul the crossings.

Construction of Crossings.—The construction of the crossing frogs has already been described, and it is, perhaps, best to rivet them to base plates, particularly where they carry heavy traffic. The riveting must be good and substantial work, or the rivets will work loose and the frogs will clatter. The rails and frogs may be supported in either of three ways: (1) By ordinary ties placed at such angles as to afford the best support of all the rails; (2) Upon long switch

ties or timbers; (3) By framed timbers which are halved together under the crossing frogs and give a continuous bearing to each rail. Where ties are used at a right-angled crossing they are usually laid at an angle of about 45°, but the arrangement cannot be anything but unsightly, and is inferior to the second plan. The third plan is the most substantial, especially for angles of nearly 90°, and it affords the best resistance to lateral shifting or creeping of the crossing. Where a main line crosses a minor line at right angles, one track may have a longitudinal timber about 6×10 ins. or 10×12 ins., from 12 to 14 ft. long, under each rail, while the other track has ordinary ties. Tie-plates should be placed on the longitudinal timbers.

The Chicago & Eastern Illinois Ry. uses ties and long timbers 8×10 ins., 10 ins. apart, for crossings of less than 75°, as shown in Fig. 87, and uses framed timbers for other angles. The Chicago, Burlington & Quincy Ry. usually employs sawed ties, except at right-angle crossings, where framed timbers are used, as shown in Fig. 88. Some roads use framed timbers in all cases, but others

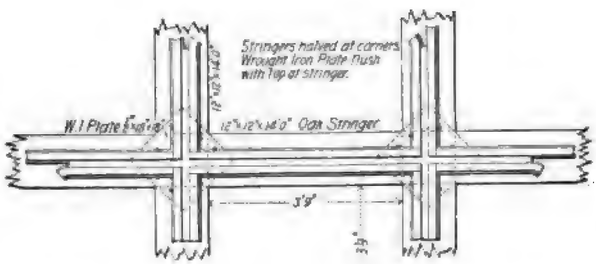


Fig. 88.—Track Crossing Laid on Framed Timbers.

use switch ties (about 7×9 ins., 8 ins. apart) for all crossings up to 80°. The earth and old material should be dug out and replaced with broken stone or clean gravel to a depth of 12 ins. on banks, and even deeper in cuts where the drainage is bad, while tile drains are sometimes laid. It is very important to have a thoroughly good foundation at the crossing.

CHAPTER 10.—BRIDGE AND TRESTLE FLOORS.

While solid floors for steel bridges are coming into more general use, the common form is still the open floor, consisting of sawed ties laid upon the track stringers of through bridges or the top chords of deck bridges, and secured by hook bolts taking hold of the flanges of stringers or chords. In rare cases, the rails are laid on longitudinal timbers, both on open and solid floors. In one system, these timbers are laid on steel stringers between the floor beams. In designing the floor of a bridge or trestle, the emergency of derailed trains must be provided for. This need involve but little additional expense, but may save many lives and many thousands of dollars in case of a derailment. This is discussed below in relation to guard rails. Bridge ties are usually 8×8 ins. to 10×12 ins., but sometimes 8×16 ins., in section. The length is from 9 to 14 ft. for single track; in some cases the standard length is 10 ft. while every fourth tie is 14 ft. long, carrying two lines of plank. On double track, timbers 24 ft.

long may be used, carrying both tracks. This is the practice on the New York Central Ry., the 24-ft. ties being 10×8 ins. (on edge) with a guard timber at each end and in the middle; they are spaced 12 ins. c. to c. and boxed out over the girders. Sawed ties of white oak or yellow pine are commonly used, the latter being less liable to warp; Douglas fir is also used. They should not be more than 4 ins. apart in the clear, and kept from bunching under derailed wheels by having the guard timbers boxed out for each tie, or by having spacing blocks fitted between the ties. The ties are frequently boxed out over the girder or stringers, so as to be held laterally. Every third or fourth tie is usually fastened to the flanges of steel girders or stringers by ¾-in. hook or through bolts; or to timber stringers by drift bolts, screw-bolts or lag screws about ¾×12 ins. On long trestles or deck bridges there should be a plank footwalk at one side or between the tracks; or else refuges should be provided at intervals. The latter (on trestles) may be conveniently located where the water barrels for fire protection are placed. Some roads lay a line of planks 2×12 ins. between the rails, and nailed to the ties, for the convenience of employees. Tracks on bridges and approaches should be kept in good line and surface; they should be firmly bedded at the ends of the approaches, so as to avoid shocks when trains come upon the bridge at high speed.

Solid floors for steel bridges have advantages in safety, permanence and smooth riding. The first cost is, of course, greater, but there is a decided saving in maintenance work, while with a ballasted floor the track maintenance can be regularly attended to by the section gangs instead of by the bridge gangs. Ballasted floors are generally preferable to bare floors. They enable the standard track construction to be carried across the bridge, while the extra dead load not only requires a heavier construction of bridge, but the ballast practically eliminates impact stresses and also prevents much of the vibration which causes objectionable noise. This last point is very important for street bridges, as the thundering sound of trains passing is likely to frighten horses. The depth of ballast should be at least 8 ins. In many cases the solid floor is built up of transverse troughs of rectangular or trapezoidal section, but sometimes consists of flat deck plates on transverse I-beams. It has been suggested that ballast tends to corrosion of the floor, but experience does not sustain this. In some cases the troughs are filled with ordinary or asphaltic concrete. Floors of longitudinal troughs, carried on the floor beams, or forming in themselves a self-supporting floor, have been used. Concrete slab floors are also coming into use. In Europe, the floor is sometimes made to form a deep trough for each rail, in which derailed wheels would run safely. No general plan can be laid down for solid floors, but various designs may be made to suit different classes of bridges. The design should be made with special regard to strength, safety, noiselessness, maintenance, weight and economy.

Both ballasted and unballasted solid floors have been used in track elevation work, but the former are now generally used. For parallel tracks, plate-girder through bridges are mainly employed, but where switches, crossovers, etc., have to be provided for, a flat deck, or a self-supporting trough floor must be used. Asphalt concrete is largely used by the Chicago & Northwestern Ry. for filling trough floors and covering steel deck floors to protect them from the ballast. In the latter case it is from 2 to 5 ins. thick, sloped for drainage. The metal is heated to insure a close adhesion of the hot mixture. On some work, the trough floor itself forms the bridge, being supported on the abutments

and on cross girders carried by columns in the street. In this case the troughs are longitudinal, 18 ins. deep, 15 ins. wide, and in spans of 12 to 30 ft. Facia girders retain the filling and ballast. At the new Washington terminal, the bridges over streets are composed of 24-in. I-beams, 18 ins. apart, in 26-ft. and 28-ft. spans. These are embedded in concrete which extends 2 ins. below them; above this is a ¾-in. layer of waterproofing and 5½ ins. of concrete reinforced by ⅜-in. steel bars to prevent cracking. Upon this is the ballast. Another arrangement is to lay I-beams between the flanges of plate-girder spans, and to cover this with 2-in. or 3-in. creosoted planking; the seams are calked, and the floor covered with layers of felt in hot pitch or asphalt compositions. Upon this is a layer of brick or a bed of sand and gravel to protect it from the ballast proper. A 4-in. concrete slab floor on the I-beams is sometimes used in place of the timber deck.

Where unballasted steel floors are used, they are usually of the deck-plate type. Transverse 12-in. I-beams about 15 ins. c. to c. are laid on the bottom flanges of the girders and covered with a deck of $\frac{7}{16}$-in. plates. In one system, a 10×4-in. channel is riveted to the floor for each rail, and has a 1½-in. wooden filler or longitudinal covered with a ½-in. plate on which the rail is laid. The fastenings are U-bolts, with saddle pieces under the floor. In another design, each rail is laid on vulcanized fiber plates on a ½-in. steel plate 16 ins. wide, having riveted along each side an angle 3½×5 ins., with the 3½-in. leg horizontal and turned in toward the rail. At the back of this is a smaller angle riveted to the deck and the 5-in. leg. A third practice is similar, but with a single outside guard-rail angle 4×6 ins. (6-in. leg horizontal and inward), or two Z-bars forming a trough. A plan similar to that first described, but with a ½-in. deck plate, is used by the Delaware, Lackawanna & Western Ry.; each rail is laid on a ¾-in. plate of vulcanized wood (for insulation) in a 15-in. channel, while a 6×4-in. guard angle is riveted to the deck and one side of the channel. Continuous oak strips in 7½-ft. lengths are laid on the rail flanges, fitting between the rail web and the channel. The attachment bolts pass through these fillers. In a similar arrangement used on ordinary bridges, the 20-in. I-beams are 4 ft. apart, with stringers between (each composed of two 10-in. channels and a 10½-in. web plate); each 4-ft. span has three crossties 10×10 ins., notched for the web plate, and carrying 15-in. channels for the rails. The channels are fastened by 8-in. lag screws. Between them is a plank floor covered with asphalt and gravel. With trapezoidal troughs on the bridges of its track elevation work in Chicago, the Illinois Central Ry. places ties on top of the inverted troughs. A bridge on the Kansas City Outer Belt Ry. has rectangular troughs 11 ins. deep and 13 ins. wide; in these are 10-ft. ties 8×10 ins., set on edge and resting on blocks 4½×8 ins., 2 ft. long. In both these cases ballast is omitted. Unballasted steel floors are usually protected by asphalt paints or compositions, the adhesion of which is improved by cleaning and heating the metal (see Engineering News, Oct. 29, Nov. 12, 1903; May 5, 1904; Feb. 16, Sept. 7, Nov. 2, 1905).

Reinforced-concrete floors for ordinary bridges are being introduced. On a through-truss bridge of the Chicago, Burlington & Quincy Ry. the floor beams are 9½ ft. c. to c., with eight lines of I-beams between them. Upon this framing is a 4-in. floor slab, 13 ft. 4 ins. wide, with 8-in. curbs 16½ ins. high, to retain the ballast. A 1:2:4 concrete is used, coated with asphalt, and drain holes are cored in the floor. Ballast is filled in level with the curbs, and inside guard

rails are laid on the ties. The weight of this floor is 2,500 lbs. per ft. of single track, including ballast and track. For track elevation work, the road uses self-supporting slab floors on steel or concrete girders carried by columns at the street curb line. The slabs over the street are 24½ ft. long, 7 ft. wide, from 30 to 33 ins. thick; they contain 16¾ cu. yds. and weigh 36¾ tons. The smaller slabs for the 10-ft. sidewalk spans weigh 8 tons. The concrete is a 1:2½:4 mixture, using 1½-in. stone; or a 1:4 mixture using pit gravel with all stones over 2 ins. removed. In a plan proposed by J. W. Schaub, a concrete slab floor is used, and is made of extra thickness at the middle. Longitudinal timbers at the sides carry the rails and are bolted together through the middle portion.

For plate-girder deck bridges, ballasted floors of transverse troughs or old rails have been used to some extent. The Chicago & Northwestern Ry. has some double-track bridges of this type, with floors of transverse troughs 28 ft. long, overhanging the outer girders about 4 ft. Along each side is a light plate girder 21 ins. deep, with gusset plates riveted to the floor, and gravel ballast is filled in to a depth of about 25 ins. above the troughs, the ties being embedded in the ballast. The Michigan Central Ry. puts the girders 9 ft. apart, and upon them are laid 10-in. I-beams 15 ft. long, 12 ins. c. to c., with a ⅜-in. deck plate coated with asphalt. Curbs of angles 3½×7 ins. retain the ballast. Several railways use a concrete floor. On the Chicago & Eastern Illinois Ry. the floor is 14 ft. wide (for single track), 10 and 7 ins. thick at middle and sides, and with curb walls 18×12 ins. Fig. 89 shows a floor of old rails

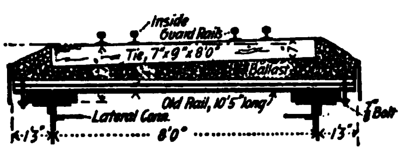


Fig. 89.—Bridge Floor of Old Rails; Chesapeake & Ohio Ry.

on a deck bridge of the Chesapeake & Ohio Ry. The 70-lb. rails are spaced 6 ins. c. to c., so as to fit between the rivet heads. The rails are 10 ft. 5 ins. long for single track and 23 ft. 5 ins. for double track. An angle iron 6×6 ins. on each side of the floor is secured to the extra wide bottom cover plate of the chord by ¾-in. bolts, 12 ins. apart. To the vertical flange of this angle iron is riveted a plate ⅜×12 ins. to retain the ballast, which is only 4 ins. deep under the ties. The floor is well coated with tar, and the spaces between the rails allow for drainage. An angle iron retains the ballast at each end of the bridge, and a plate covers the space between the bridge and the back wall of the abutment. A greater depth of ballast and greater width of floor would be preferable. Solid timber floors are extensively used, composed of bridge ties laid close together. On the Chicago, Milwaukee & St. Paul Ry., the girders have no cover plates, and the web plates project ½-in. above the chord angles. The ties are notched to rest on the chord angles, and hook bolts attach the ties to the girders. On the Eastern Ry. of New Mexico, the timbers are 10 ft. long and 10 ins. deep; on high bridges some of them are 18 ft. long, to carry plank sidewalks, which are covered with 2 ins. of stone screenings as a protection against fire. The floor may be covered with ballast, carrying the usual arrangement of ties; or the rails may be laid directly on the floor, which is then lightly covered with gravel.

Ballasted floors for trestles are coming largely into use and are of three classes: 1, With longitudinal stringers or square timbers placed close together (using smaller ones at the sides); 2, With transverse ties laid close together; 3, With 3×12-in. planks across the ordinary stringers. The ballast is retained by a curb timber about 10×12 ins. secured by knee braces on the floor, or by inclined anchors passing through the timber and spiked to the floor. With coarse ballast, the stringers or ties may be ¼-in. to ½-in. apart. The depth of ballast varies from 5 to 10 ins. In some cases, as on the Wisconsin Central Ry., the ordinary floor construction is used, but planks are laid on the stringers as fillers between the ties, forming troughs for ballasted floors. On the Illinois Central Ry., there are ten longitudinal timbers, 7×16 ins., covered with planks 3×6 ins. ×14 ft. long, laid transversely. Coping timbers 6×8 ins. are bolted on the ends of the floor planks and through the outside stringers at three points in each panel with ¾-in. bolts, 29 ins. long. These timbers are separated from the floor by 1-in. cast-iron separators to allow for drainage. This gives a deck 14 ft. wide over all. The bents are spaced 13½ ft. c. to c., and the eight inside stringers are 14½ ft. long, lapping on the caps. The two outside stringers are laid with butt joints and are 27 ft. long. The caps are 12×14 ins., 16 ft. long. On each side of the caps, planks 2×6 ins.×14 ft. long are spiked to the under side of the stringers by ¾×6-in. spikes to prevent creeping of the floor upon the caps. The timber used is all creosoted pine. The ballast is 12 ins. deep below base of rail. The Kansas City Southern Ry. uses a solid floor of ties 7×8 ins., 10 ft. long, sized to 6¾ ins. thick; and over each bent is a 7×8-in. tie on edge, boxed out over the stringers. Guard timbers 5×20 ins., laid flat, are at the ends of the floor and bolted to every fourth tie. Tie-plates are placed on alternate ties. Hot coal tar is applied to the floor, and 3 ins. of washed gravel laid upon this as a protection against fire. Other roads use a similar construction, but a ballasted floor is generally considered preferable. The solid floors have the following advantages: 1, Safety from fire; 2, Low cost of maintenance; 3, An easy riding track with less liability of damage in case of derailent; 4, With a ballasted floor the section gangs can maintain the track in line and surface, independent of the bridge gangs.

Open culverts and short trestles for roads, cattle passes, etc., may often be advantageously replaced by solid embankments having concrete arches or iron pipes. In fact, the extensive introduction of concrete arches, girder spans and box culverts, with or without embankments above them, has materially reduced the maintenance expenses and increased the safety of traffic by eliminating short open-floor timber structures which are liable to be burned or washed out. Where the depth is insufficient for an embankment, concrete or masonry abutment walls may be built to carry a solid floor of I-beams, old rails or steel troughs. The Michigan Central Ry. uses concrete side walls, spanned by plate girders carrying I-beams 12 ins. c. to c., with ⅜-in. deck plates. The ballast is put over this to a depth of at least 12 ins. under the ties. The Atchison, Topeka & Santa Fé Ry. lays a floor of plank, 12 ft. long, with 5×8-in. curb timbers to hold the ballast. On the Virginia Ry., 6-ft. open-top culverts have concrete inverts, walls and portals. Under each rail are three 10-in. I-beams, 8 ft. 4 ins. long, carrying ties 7×9 ins., 2 ins. apart. The spaces between the ends of the ties and the concrete portal girders are covered by longitudinal planks 4×12 ins. On the New York Central Ry., culverts and spans up to 12 ft. have floors of old rails embedded in concrete (5 ins. thick over the rails), and covered

with a layer of gravel, upon which is the stone ballast. The concrete forms a curb wall at each side. The rails are given a coat of red-lead and a coat of bridge paint. They are laid on their flanges, and close together, but beneath each track rail there are six inverted rails fitted between the others. In some cases, however, I-beams alternating with the rails take the place of the inverted rails. A 4-ft. span would have two 12-in. or four 8-in. I-beams under each rail; while a 16-ft. span would have from three 15-in. to five 12-in. I-beams under each rail. Ballasted floor culverts on the Southern Pacific Ry., Fig. 90, have at each end four piles carrying a cap 12×12 ins., 12 or 13 ft. long, with 8-ft. or 9-ft. ties. Upon these is a close floor of longitudinal timbers from 6 ins. deep for 4-ft. spans to 8 ins. for 10-ft. and 12 ins. for 14-ft. spans. Curb timbers retain the ballast, which is 9 ins. deep under the ties, and planks behind the piles hold back the face of the bank. For crossing irrigation ditches this railway has used under each rail a pair of 12-in. channels placed back to back and having saddles of steel channels riveted between them. Creosoted blocks 4×12 ins., 12 ins. long, rest on the saddles, and the rails are bolted to the latter.

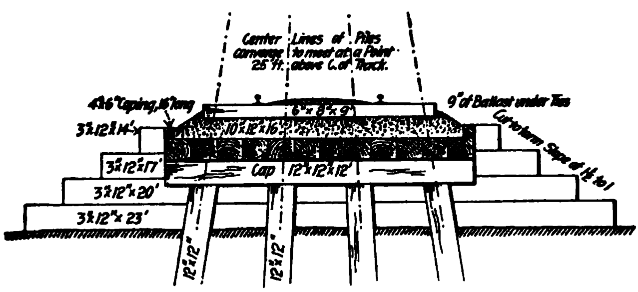


Fig. 90.—Ballasted Culvert; Southern Pacific Ry.

It would be better to use stringers instead of blocks, to give a continuous bearing for derailed wheels. The channels rest on shoes on 12×12-in. cap sills, and weigh 30 and 50 lbs. per ft. for spans of 12 and 15 ft. For crossing gutters which have to carry surface water, the railway sometimes uses two pieces of old rail bolted together at intervals of 18 ins., the track rail resting on spacing sleeves on the bolts.

Corrosion and Fire.—On steel structures, corrosion is often caused by brine dripping from refrigerator cars. On structures over the tracks, corrosion is often caused by smoke and gases, while the cinders from the engine stacks have a sand-blast effect in cutting paint put on as a protection. The former trouble may be avoided by putting a plank flooring under the ties, made water-tight and well coated with tar. This should be slightly inclined to drain to a suitable gutter. The Illinois Central Ry. proposes to put gutters of galvanized iron between the ties to protect the structure from brine and from the rust of the rails, as the latter destroys the paint. The gutters are 4½ ft. long and 6 ins. wide, with a 2-in. flange at each side to rest on the tie. The depth is 2 ins. at the inner end (near the middle of the track) and 6 ins. at the outer end. On solid floors, experiments have been made with asphalt and paint, and with a tar and gravel composition. The floor must be made water-tight and itself protected against corrosion. It has been suggested that the cars should be fitted with tanks to collect the drippings and prevent this trouble.

For the corrosion due to locomotives, a plank sheathing beneath the floor beams has been used in some cases, while in others the floor is of steel I-beams with concrete arches between them, the concrete enclosing the steel work. Pockets where gases may collect should be avoided or filled up.

On wooden structures, special protection against fire should be considered, as a spark or cinder from an engine may result in the burning of the structure. For this purpose, sheets of iron are sometimes laid over the caps and stringers, having the sides bent down at an incline. The Northern Pacific Ry. has tried the use of a continuous deck of galvanized iron sheets in 5-ft. lengths, the seams made with copper rivets 1 in. apart in order to leave sufficient opening for the escape of water and melting snow. This deck extends beyond the ends of the ties, and the rails and guard timbers are laid upon it, the spikes and bolts passing through the plates. The use of solid floors for trestles, with ordinary ballast and ties, or with a light protective covering of gravel, is now very general, and some systems of construction have been described above. Water barrels are usually placed at intervals along trestles.

Guard Rails and Rerailing Devices.

Bridges should be equipped with means for protecting trains in case of derailment. A substantial floor construction to safely carry a derailed car or train is one requisite, as already noted. In addition, means should be taken to prevent derailed cars from striking the trusses or falling over the bridge, and also to catch and rerail these. It has been proposed to lay each rail in an iron trough (see Bridge Floors), or in a 15-in. rolled channel, leaving about 6 ins. clear between each side of the rail head and the flanges of the channel. It is questionable, however, whether these flanges would serve the intended purpose effectively. As a general thing all bridge floors are provided with guard timbers outside the rails. These are usually of oak, 6×8 ins. (which is too small) or 8×10 ins., laid flat and boxed out 1 to 1½ ins. for the ties, to hold these in place. They are secured to every third or fourth tie by a ¾-in. or ⅞-in. bolt, the head resting on an ordinary washer or in a cup washer let into the timber. On steel structures there may be hook bolts engaging with the flanges of the girders or stringers. On trestles with jack stringers the bolts may pass through the stringers. At joints, the timbers are usually scarfed, with a bolt passing through the joint and tie.

The timbers are usually set 10 to 18 ins. from the gage side of the rail head, or 7 to 9 ft. apart. The sooner a derailed wheel is met and guided, the less is the liability of its causing trouble, and with guard timbers more than 8 ft. apart the wheels have a chance to turn or slew to such an angle as to be likely to burst the guard or to climb over it. The guard timbers are more thoroughly effective if faced with angle irons on the top corners. In some cases the guards serve merely to keep the ties from bunching, being so far apart that a derailed car would strike the bridge truss before the wheels encountered the guard. This is not good practice, but on wide bridges with long ties, extra timbers are sometimes placed near the ends of the ties. The purpose of the wider spacing is claimed to be to provide for wheels very far off the track, but these should be provided for by flaring the timbers out on the approach for a distance of from 30 to 60 ft., so as to catch any wandering wheels and guide them into position for crossing the bridge in safety. This important practice, however, is now generally neglected, the guard timbers ending with the bridge floor. In this respect

present practice is decidedly inferior to that of 10 or 20 years ago. On some roads guards 10 ins. from the track rails extended 110 ft. from the end of the bridge (and 10 ft. beyond the inside guard rails), being then 10 ft. apart, on ties 12 ft. long. These guards extended 10 ft. beyond the end of the inside guard rails, being there 9 ft. apart in the clear. On the Delaware & Hudson Ry. the guard timbers are 8 ins. from center of the track rails, and extend 8 ft. beyond the bridge, where they are 8 ft. apart. This angle is much too sharp, but on most roads, the guard timbers do not extend beyond the bridge floor. Long flaring guard timbers should be provided, as noted, and should be laid on long ties firmly bedded and well tamped in good ballast for their entire length. In some cases, bumper posts are placed on the approach in line with the bridge trusses, so that a derailed car far enough off the track to strike the truss would have its trucks stripped from under it before reaching the structure. These bumpers may be formed of three piles in a cluster or a timber 16×16 ins., 10 or 12 ft. long, with 4 ft. above ground.

Inside guard rails are very commonly used, either with or without the outside guard timbers, but it is better to use both. On some roads, the inside guard rails are considered unnecessary, but they are really of greater importance than the outside guard timbers, and it is unwise to rely upon the latter alone. In a derailed car, the shock of a leading wheel striking the outside guard tends to slew the truck to a greater angle and so make it even more liable to burst or climb the guard. The inside guard, however, will engage the back of the rear wheel, and so prevent the truck from slewing to a dangerous angle. It has been objected that inside guard rails are likely to catch a wheel far out of line and guide it to the wrong side. Experience shows, however, that wheels rarely swerve as far as the center line of the track, and would in any case be guided back by flaring guard timbers, which should extend beyond the inside guard rails. The inside guards are new or old rails, well spliced and spiked; they are spaced 6 to 12 ins. clear from the gage side of the track rails, the spacing being sufficient to admit derailed wheels. The Michigan Central Ry. uses three lines of rails, those at each side having the centers 13½ ins. from the gage side of the track rails. Heavy angle irons, with the horizontal flange set either towards or away from the track rails, are sometimes used instead of rails. In some cases, also, there are inside guard timbers, with an angle iron on the top corner, or laid on the ties and bolted through the guard timber so as to form a path for derailed wheels. The guard rails should be extended about 30 to 60 ft. on the approach, being gradually brought together and bolted to an old frog point or special point, beveled so as not to catch loose chains or brakebeams. In some cases, the ends are bent down vertically to lie between the ties. There should be rail braces inside the curved rails. At the leaving end of the bridge on double track, the rails need extend but a few feet beyond the structure.

Rerailing devices which will replace derailed wheels upon the rails are not so generally used as they should be, in view of their importance as safety devices and of the experience as to their efficiency in preventing serious accidents. Their omission is a serious defect in bridge floor design. They consist of inclined planes fitted between the track rails and the guard rails and timbers, so that derailed wheels are carried up the incline, and guided laterally until their flanges drop into position on the inside of the rail head. One form is shown in Fig. 91. The rerailing frog was invented by the late Charles Latimer, but the patents expired long ago. In the modified Childs-Latimer rerailing guard, as standard

on the Ontario & Western Ry., there are four inclined planes of cast iron, two on each side of the rail. These are firmly bolted together, although the strain upon them is not severe, the wheels being already under control by the guard rails. The outside planes are flush with the top of the rail for the rear half of their length. The outside wheels ride up their flanges, and being thus of larger diameter they tend to roll inward to the track rail. The inside incline begins just before the crotch of the rail becomes too narrow to admit a wheel; it has a steep plane to raise the wheel at once to a position where the tread can slide over on the track rail. This casting, therefore, is kept about 1¼ ins. below the top of the rail. The rerailers are usually placed over the abutment, and the inside guard rails are brought to a point at about 20 ft. beyond the bridge. The outside timbers extend beyond the bridge for 6 ft. and then flare out for 14 ft. to an end spacing of 14 ft.

It has sometimes been considered best to place the rerailers about 50 ft. to 100 ft. from the bridge, so that cars too far out of line to be rerailed will be wrecked on the approach instead of on the structure, but such cars would be

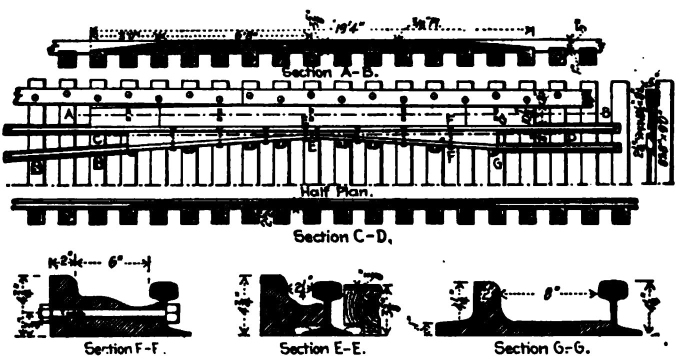


Fig. 91.—Rerailing Device for Bridges.

guided by flaring outside guards extending beyond the inside guards, as already described. The Southern Pacific Ry., however, places the rerailers 30 to 50 ft. from the bridge, the guard timbers not extending on the approach. The outside casting or rerailer is about 8 ft. long, inclined for about 30 ins. and having riveted to the top a steel plate level with the rail head. The inside casting begins 2 ft. beyond, and is inclined for about 24 ins. The rails and castings rest on tie-plates and beneath them, at the high end of the incline, is an inverted transverse rail serving as a tie bar. The inside guard rails are old 62-lb. rails carried in combined chairs and spacing blocks to bring them level with the track rails. They give a 3-in. flangeway, and are brought to a point in about 25 ft. beyond the rerailer. Where no rerailers are used, the guard rails are 8 ins. from the track rails, and extend about 50 ft. upon the approach. The outside guard timbers are 7 ft. 5½ ins. apart in the clear.

Inside guard rails should be used on ballasted floor trestles and on masonry viaducts or bridges, especially as the latter usually have the track level with or even above the coping. All small trestles for culverts, waterways, etc., are a source of danger, and should have inside guard rails at least. Small structures of this kind, however, too often have short ties, with mere sticks of guard rails on the ends, while the ballast slope is continued right up to the floor, so that

a derailed wheel would strike the end of the structure instead of running across it. Trestles with long ties may have jack stringers under the outer guard rails to prevent the ties from being tilted up by derailed trucks. Trestles and bridges for electric railways are very often deficient in guards, although with light cars run at high speed there is often great danger of derailment. In fact serious accidents have happened in this way.

Examples of Bridge Floors.—The standard floor of the New York, New Haven & Hartford Ry., Fig. 92, has ties 11 ft. long for single track and 24 ft. for double track, all 8×8 ins., 8 ins. apart (which is too far). The outside guard timbers are 6×8 ins., laid flat, boxed out ¾-in. for the ties, and faced on the upper corner with an angle iron ½×2½×3 ins., secured by countersunk $\frac{5}{16}$-in. screws, 3 ins. long, 24 ins. apart on the top and side, staggered. The timbers are 10½ ins. from the outside of the track rails, and do not extend beyond the bridge. Formerly they were flared out till they were 10 ft. apart at 83 ft. from the edge of the bridge, the end ties being 12 ft. long. They ended 8 ft. beyond the point of the inside guard rails, being 9 ft. apart in the clear opposite the point. The inside guard rails are 8 ins. clear from the track rails to a point 15 ft. beyond the abutment, whence they are inclined on a flat curve for 60 ft., until they meet at a point. The Wabash Ry. uses ties 8×8 ins., 10 ft. long for deck plate girders and stringers 6 ft. 6 ins. c. to c.; ties 8×10 ins., 12 ft. long, and 8×12

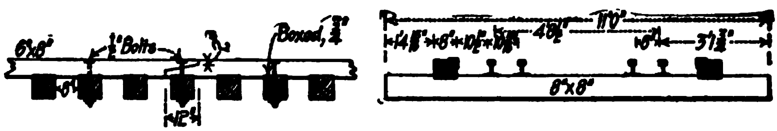


Fig. 92.—Bridge Floor and Guard Rails; New York, New Haven & Hartford Ry.

ins., 14 ft. long, for deck trusses or girders 8 ft. and 10 ft. apart respectively. The ties are spaced 14 ins. c. to c. and boxed out 1 in. (maximum 2 ins.) over girder or stringer flanges. The outside guard timbers are of long-leaf yellow pine 6×8 ins., boxed out to 5 ins. over the ties; they are in 18-ft. lengths with splices over ties. The minimum spacing from gage side of rail is 14 ins., varying on account of the spacing of girders. At every fourth tie, each guard rail has a ¾-in. bolt, with hook 1¾ ins. long, engaging with outside flange for girders spaced 6 ft. 6 ins., or inside flange for 8 ft. or 10 ft. spacing. The square nut and Eureka nut lock are on the guard timber. The inside guard rails are 60-lb. rails, 8 ins. from the track rail; they extend 60 ft. beyond the bridge, parallel with the track rails for 30 ft., then brought together to an end casting. The track and guard rails are spiked to every tie. The Michigan Central Ry. has oak ties 8×10 ins., 14 ft. long, 13 ins. c. to c. The outside guard timbers, 6×8 ins., are not boxed for the ties; they are 12 ft. apart, with a bolt at every fourth tie, and a 1×10-in. drift bolt into the other ties. Every fourth tie also has ¾-in. hook bolts holding the outer flange of girder or stringers. Three parallel lines of inside guard rails are used; one in the center line of the track and the others with their center lines 13½ ins. from the gage side of the track rails. The ends are bent down to lie between the ties, and pass through slots in flat plates secured to two ties by screws.

The Philadelphia & Reading Ry. uses ties 8×10 ins., 12 ft. long, boxed out over the chords (6½ ft. c. to c.) and held laterally by two plates ⅜×3×4 ins. under each fourth tie. The plates rest against the outer edges of the chords

and each is held by two lag screws ¾×7 ins. The ties are spaced 14 ins. c. to c. On double track, blocks 2×8×24 ins. bridge across the 12-in. space at the ends of every third tie; these carry two planks 2×10 ins. On single track, one plank is laid between the rails. The track rails are laid on tie-plates, with four spikes to each rail. The inside guard rails are laid on the ties and give 8 ins. clearance. The outside guard timbers are 6×8 ins., laid flat, with a ¾×10-in. lag screw at every fourth tie, and ½×10-in. boat spikes at intermediate ties. These timbers are 13 ins. clear from the outside of track rail. On curves, oak blocks carry the track rail, guard rail and guard timber on the high side; on the low side, the outside guard timber is set 5 ft. from center of track.

The Boone viaduct of the Chicago & Northwestern Ry. (half a mile in length) has a floor 25 ft. wide between the parapet posts, with two tracks 13 ft. c. to c. and four lines of deck girders 6 ft. 6 ins. c. to c. Outside of the girders are triangular web-brackets (the full depth of the girders) carrying the parapet posts. These brackets are connected across the top by transverse angles 6×4 ins., 30 ft. long. The rails for each track are laid on separate ties; these are of yellow pine, 8×8 ins., 12 ft. long, 12 ins. c. to c. Yellow-pine guard timbers are laid along the inner ends. Inside of each rail is an angle guard rail 6×4½ ins., with the larger leg horizontal and facing the rail. This is backed by a plank 4×10 ins., while a similar plank is placed close to the outside of the rail. An unusually heavy parapet or hand rail is used, with posts of 10-in. channels set edgewise to the track; these are riveted to the web brackets and have outside braces to the ends of the transverse angles. The posts are capped with a heavy bulb angle, the height from rail to top of angle being 4 ft. 5 ins. At four points on each side there are refuges for hand-cars, the width over the two refuges being 35 ft. On the Thebes cantilever bridge the ties are 10×10 ins., 5 ins. apart, laid directly upon the stringers and carrying 8×8-in. guard timbers boxed out for the ties and bolted to alternate ties. The inside guard rails are steel angles, with the vertical leg facing the rail and 8 ins. from it. Table No. 14 gives particulars of bridge floor construction.

TABLE NO. 14.—BRIDGE FLOORS.

	Ties.				Guard-rail spacing	
Railway.	Wood.	Size. ins. ins.	ft.	Spacing. ins.	Inside. ins.	Outside.. ins.
A., T. & S. F. . .	Long-leaf yellow pine; oak	8× 8	×12	6	8	17½
Balt. & Ohio . .	. . . .	8× 8 to 8×16	× 9	6	10	15
C., B. & Q.	White pine; fir	8× 8 to 8×12	×10	12 c. to c.	9½	22½
Del. & Hudson .	Yellow pine.	9× 9 to 9×11	× 9	6	8	8+rail
Mich. Central *	White oak; Douglas fir. . .	6×10 to 8×10	×14	3	12½	43¾
Phila. & Read..	Long-leaf yellow pine	8×10	×12	14 c. to c.	8	13+rail
So. Pacific	Creosoted pine.	8×10	×10	8 (12 c. to c.)	8	16½

* Ties 6×10 ins. on timber structures; 8×10 ins. on steel structures.

Elevated Railways.

The floor and track construction of elevated railways resembles that of bridges, except that there are generally inside and outside guard timbers secured to the ties by wooden pins or iron screw bolts, the nuts of the latter being usually in

cup-shaped washers let into the tops of the timber. These timbers are sometimes faced with angle iron on the top inner corners, and may be reinforced by additional outside timbers on curves, while the inside timbers are replaced by iron guard rails on sharp curves. The original track of the South Side Elevated Ry., Chicago, is shown in Fig. 93, but some changes have been made, as noted below. The wide spacing of the ties is an objectionable feature. The purpose is to avoid obstructing the light to the streets, but with such very wide spacing heavy planks might be laid in the spaces between the rails and guard timbers to carry derailed wheels. The 80-lb. rails (of Am. Soc. C. E. section) are secured by screw spikes $\frac{7}{8} \times 5\frac{1}{2}$ ins. to long-leaf yellow-pine ties 6×8 ins., 8 ft. long, 18

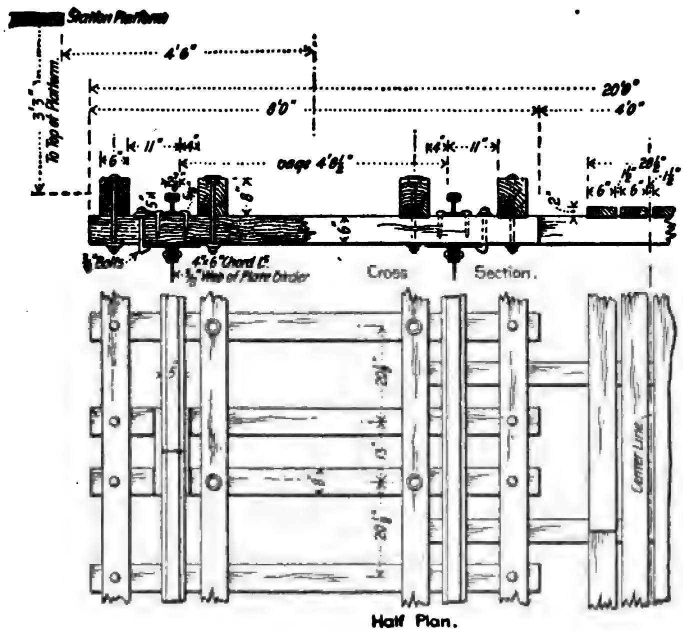


Fig. 93.—Track and Floor System; South Side Elevated Ry. (Chicago).

ins. c. to c.; every fourth tie is 9 ft. long to carry the insulated support of the third rail. Steel tie-plates are laid on every tie. Every alternate tie is fastened to the top chords of the girders by $\frac{3}{4}$-in. hook bolts, and the inside guard timbers are bolted to the same ties. The inner guard timbers are 6×6 ins., 4 ins. from the rail; the outer guard timbers are 6×8 ins., on edge, bolted to the ties to which the inner guards are not fastened. On curves, an 80-lb. inside guard rail is bolted to every tie, and wedge-shaped ties are used to give the superelevation. The line is operated by electricity, and the third rail for each track (not shown) is carried on insulators outside the outer guard timbers; the heads of these rails are $11\frac{1}{2}$ ins. above the ties, with the center line $20\frac{1}{2}$ ins. from the gage side of the track rail. Between the tracks are ties 8 ft. apart to carry the conduit or trunk for the electric cables; this is 38 ins. wide and forms a walk. Where these are not used, three or four lines of plank 2×6 ins. may be laid between or outside of the tracks for the convenience of trackmen and employees;

the outside walks are usually protected by gas-pipe hand rails. The Boston elevated railway uses hard-pine ties 7×8 ins., laid flat, spaced 8 ins. apart; they are boxed out for the girders and each is secured to the latter by two hook bolts. The ties are 8 ft. 3 ins. long, every fourth tie being 1 ft. longer to carry the insulated supports for the third rail. The 85-lb. rails are laid on tie-plates and spiked to the ties; they have the Continuous joint, with four bolts. Creeping is prevented by anchor plates made to fit the rail and top of tie-plate; these are bolted to the rails and spiked to the ties. The two inside guard timbers are 6×6 ins., and the outside timbers 6×9 ins. (on edge); they are spaced 8 ins. and 10½ ins. from the gage side of the track rails. On curves, an inside 100-lb. guard rail is secured to the track rail by ¾-in. bolts 2½ to 5 ft. apart. Malleable iron spacing blocks are fitted between the rails, and rail braces are placed on the outside of the guard rail. There are curves of 82 ft. to 150 ft. radius, and the width of guard-rail flangeway varies as follows:

Radius. ft.	Flangeway. ins.	Radius. ft.	Flangeway. ins.	Radius. ft.	Flangeway. ins.
To 90	2⅜ to 2½	150	2⅛	500	1⅞
125	2¼	250	2	Over 500	1¾

In some cases ties have been dispensed with, each line of rails resting on wooden blocks or saddles riveted between a pair of channels placed close together and acting as guard rails. This system was originally used on the Hoboken cable line, but when electric traction was introduced cross-ties were substituted, resting on the channel stringers. This was partly on account of the attachments allowing too much lateral play of the rails to suit the narrow-tired wheels, and partly because the gear cases came too near the stringers. The Kansas City line has 48-ft. latticed trusses with top chords of two 10-in. channels, 8 ins. apart. The rails were originally laid on saddle plates riveted between the channels, but are now spiked to ties laid across the chords in the usual way. It has been proposed to lay longitudinal timbers in a similar way to the above, giving greater security than the blocks, and less obstruction to light than the ties. The latter point is important for lines built on city streets. Felt packing under the timbers might help to reduce the noise. On a part of the Chicago elevated loop, blocks were placed between the ties at each side of each rail, and planks put under them to form pockets. Gravel was then filled in half-way up the web of the rail, between the guard timbers. This had little effect in reducing noise. The gravel pulverized, and rain washed the mud through the joints so that it dropped into the streets. Much of the noise comes from the vibration of the metallic structure, but also from the rattling of wheels, couplers, gears, chains and other loose parts on the cars.

Solid floor systems have been used in some cases. The Market St. line at Philadelphia has a floor of shallow rectangular longitudinal troughs, 5×15 ins., filled and covered with concrete. The surface slopes 3% to a central drain, but curbs at the outer side and edge of drain retain the stone ballast. The concrete has a minimum thickness of 4 ins. at edge of drain; it is reinforced by longitudinal and transverse bars to prevent cracking, and has a granolithic finish. On the elevated railway at Berlin (Germany) a buckle-plate floor is used where noise would be specially objectionable. This is carried by the top flanges of the floor beams, and is covered with gravel ballast; the rails are 4½ ins. high, on ties 30 ins. c. to c. Where the question of noise is less important, 7-in. rails are carried by ties laid on the flanges of the floor beams (5 ft. apart). Between

the lower flanges of these beams are buckle plates carrying a light concrete which is filled in to the tops of the beams and covered with a waterproof coating. Holes in the plates provide for drainage, the water being carried off by gutters. The elevated portion of the Metropolitan Ry. of Paris (France) has truss spans of 72 ft. (50 ft. at stations), with transverse floor beams carrying brick jack arches. Ballast is filled in above this.

CHAPTER 11.—TRACK SIGNS.

Various marking and warning signs are required along a line of railway, to indicate distances, boundaries, special points, danger points, etc.; these are for the guidance of trackmen, enginemen, property agents, and others. In the case of new railways and the reorganization or general improvement of existing lines, it is often necessary to establish a system of signs, or to reduce a variety of styles to some standard of uniformity. The signs should be strong and durable, simple in design, economical in construction, free from ornamental molding or painting, of as few different styles as practicable, and designed especially with a view to being permanent, conspicuous and easily recognized. The signs which are for the guidance of enginemen should be set at a uniform distance from the rail, the length of post therefore varying on cuts and banks, but this cannot be universally observed. Mile posts, for instance, are often placed on the right of way, beyond the toe of the bank, instead of on the slope. These signs should be on the engineman's side (right-hand side) of the track, except where sidetracks or buildings interfere. They should never be less than 6 ft. clear from the nearest rail, and 8 ft. is a better distance, some roads specifying 6 ft. 6 ins. on embankments and 8 ft. in cuts. Signs should never be set in the ditches.

The signs may be either simple posts, or posts carrying boards of various sizes. Posts of different sizes and shapes are used for a variety of purposes, and have the advantages of simplicity and low cost. They do not allow of as much lettering as is sometimes required, and are not conspicuous enough for some of the more important signs. Larger signs may be of wood, cast iron or sheet iron, the latter being sometimes enameled instead of painted. Wooden board signs are usually of 1-in. plank, and if of large size they should have battens about 1×3 ins. screwed to the back. Iron straps or wooden strips may be nailed to the ends of the board, but the use of molding strips as a frame is not to be recommended. The boards are generally nailed, screwed or bolted to the post, and are sometimes let into it, but this latter practice involves extra work. For a long board, a strap or brace of wrought iron, $\frac{1}{2}\times1$ in., may be used, passing over the back of the post and having its ends secured to the ends of the board by $\frac{1}{2}$-in. carriage bolts. Cast-iron plates, with raised letters or figures, are quite frequently used, being screwed to the posts. Small ones may be $\frac{3}{8}$-in. thick, with rim and letters $\frac{1}{4}$-in. or $\frac{3}{8}$-in. thick, while large ones may be $\frac{5}{8}$-in. and 1-in. thick. The latter may have a rim $1\frac{1}{4}$-in. thick and $\frac{3}{4}$-in. wide. Cast-iron posts with flat disk tops are now rarely used; they are very liable to be broken and cannot be repaired. A simple, cheap and effective sign has targets of $\frac{3}{16}$-in. steel or heavy sheet iron fastened to posts of angle or tee iron or old rails or boiler tubes. Scrap material of little value can often be utilized

to advantage in this way. Old rails are sometimes used for posts, depending upon their value as scrap. Stone, in the form of posts or slabs, is sometimes used for mile posts, but rarely for any other signs. Concrete is being used for mile posts and whistle posts.

Wooden posts are usually of oak, cedar or chestnut. They should be set not less than 3 ft. deep in the ground, and deeper if the sign is high or the board large. The lower end should be coated with pitch or creosote to about 12 ins. above the ground line. The top should be cut pointed, slanting or rounded, so as to shed water, and sometimes a piece of thin sheet iron is nailed upon the rounded top, but this is rarely necessary. The edges of square posts may be chamfered, but no other decoration or trimming should be attempted. Broken stone or small field stone piled around the base of the post looks neat, protects the post from burning grass, and tends to keep weeds from growing.

There should be as little lettering as possible, and the letters or figures should be large, clear and plain, without attempt at ornamentation. In some cases the figures or letters are of malleable iron, about $\frac{1}{4}$-in. thick, so that an ordinary track laborer can renew and repaint them. Where a word is placed vertically (and this is a poor practice as a rule), it usually reads downwards, whether the letters are upright or sidewise. Caution boards with long-worded warnings in small letters are of little practicable use. They may serve to meet legal requirements in some cases, but nobody will stop to read them.

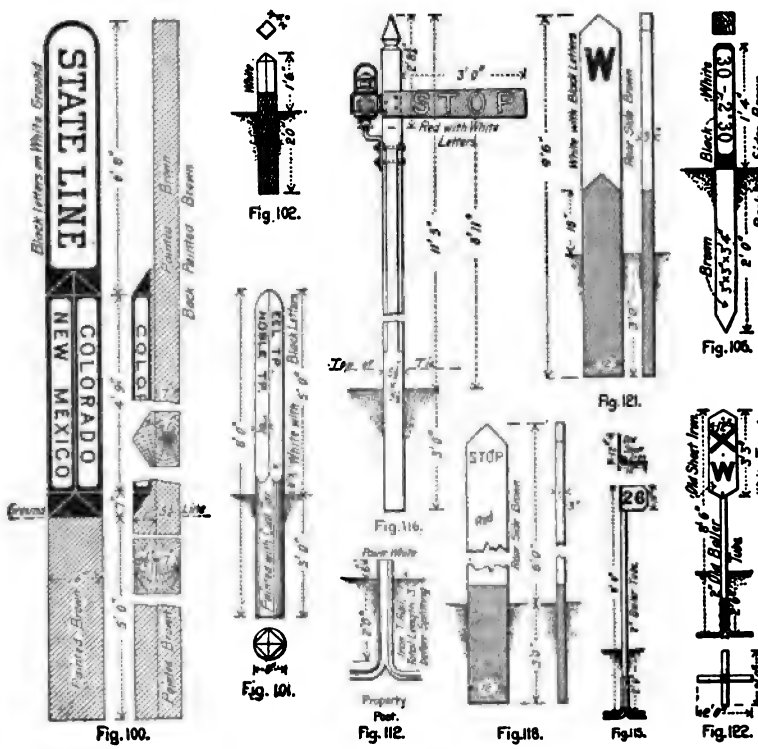
As to color, plain black letters and figures on a white ground are the most common and the most conspicuous, but sometimes the lettering is white on a black or blue ground. Two colors are usually sufficient for ordinary signs, but in some cases a third color is desirable for the back of signs, to render them inconspicuous. The third color may for the same reason be used for boundary and other signs which are not for the information of enginemen. Red and green, with white lettering, should be used for "stop" and "slow" signs respectively, although yellow is now sometimes used for the latter. White is in general the most striking color and should be liberally used. It is also the best color for signal posts, as the brown and dull ochre colors sometimes used are less distinct and tend to "kill" the brightness of the color of the signal blades. On several roads, a brown mineral paint is used for posts, and where letters or figures are to be marked, there is a white patch or panel with black border and lettering. On some roads the signs are painted twice a year (in April and October) by a painting gang, which may be accommodated in a boarding car or train.

The signs used vary on different roads, but some of the principal ones are noted below. Besides these, there are such signs as "Shut this Gate," for farm crossing gates; "Keep off the Track," at bridges and streets where people are likely to trespass; "Derail," placed at the headblocks of sidings so equipped (but not interlocked with signals). Also miscellaneous temporary or movable signs such as "Clean Ashpans Here," "Dump Ashes Here," etc.

Block Section Limit Signs.—The Cincinnati Southern Ry. places a cast-iron sign 150 ft. in advance of each automatic block signal, to mark the overlap. It is set 9 ft. from the rail. It is a triangle, with sides 8 ins. wide; the height is 3 ft., with the top 10 ft. above the rail. The sides are $\frac{3}{8}$-in. thick, with $\frac{1}{2}$-in. letters and $\frac{3}{4}$-in. edges. It is painted black, with white letters.

Boundary Signs.—Tho Atchison, Topeka & Santa Fé Ry. marks its crossings of State lines by a rather elabo ate sign, Fig. 100. It is of oak, set 13 ft. from

the rail and facing the track. County and township lines and city limits may be marked by round posts with faces flattened for the lettering, as in Fig. 101, which is that of the Pennsylvania Lines. Board signs are less frequently used. The Cincinnati Southern Ry. uses a cast-iron circle 3 ft. diameter with a horizontal diametrical cross arm for the name of the town or county. A socket at the lower edge of the circle fits upon the post, which is 9 ft. from the rail. For State boundaries it uses a 6×8-in. post, having the names of the States on the sides, and "State Line" on a horizontal arm 8×2 ins., 5 ft. 2 ins. long, passed through the post. (See also Property Posts.)



Track Signs.

Bridge Signs.—Bridges, trestles and large openings are usually numbered, for convenience of reference in regard to repair, etc. The numbering should include every opening and waterway, however small; where additional openings are afterwards provided, fractional numbers may be used. The structures or openings may be numbered consecutively from divisional points or by miles and letters, as 250A, 250B, etc.; indicating the first and second bridges beyond mile post 250. The numbers may be on iron plates or wooden boards on the portals of through bridges, or attached to posts, ¾-in. rods or old rails 4 ft. 6 ins. long, on the abutments of deck bridges or trestles. The New York Central

Ry. uses an old rail with a 24-in. octagonal target of $\frac{3}{16}$-in. steel. In some cases a wooden block of triangular section is spiked on top of the end of a tie, having the number marked on the inclined face towards the abutment. The Atchison, Topeka & Santa Fé Ry. paints the number on the end post, using a white panel with letters 5 ins. high, 2 ins. wide, $\frac{3}{8}$-in. lines.

Clearance Signs.—These are to indicate the nearest point at which the end of a car on the turnout may stand without fouling cars on the main track. This point is where the tracks are $7\frac{1}{2}$ or 8 ft. apart in the clear for tracks $12\frac{1}{2}$ or 13 ft. c. to c. They may be round or square oak stakes, about 4×4 ins., $2\frac{1}{2}$ to 4 ft. long, with the top a few inches above rail level. The post of the Baltimore & Ohio Ry. is shown in Fig. 102. They are usually placed between the tracks, and as they are liable to be stumbled over by switchmen and yardmen they should be made clearly distinguishable, being painted white, with a flat or rounded black top. A distinctive mark on the end of the tie would be as useful and avoid danger. The Canadian Pacific Ry. uses a more conspicuous sign, consisting of a tall post with a black cross arm having two white disks, and places this sign on the turnout side of the track. The Atchison, Topeka & Santa Fé Ry. uses a 3-ft. piece of old telegraph pole, painted white, and with its rounded top 4 ins. above the rail. It is set where the distance between gage lines of the rails is 8 ft. at all main-track switches, or 6 ft. 10 ins. at switches in yards and from house tracks to sidetracks. The New York Central Ry. uses an old rail 7 ft. long, $3\frac{1}{2}$ ft. above ground, with a 10-in. iron disk lettered "C." This is on the outside of the sidetrack, 8 ft. from center line, at the point where tracks spaced 13 ft. c. to c. are 12 ft. c. to c. In yards, the ties at the points where tracks approach 12 ft. c. to c. are painted white and have the edges (outside the rails) beveled.

Crossing Signs (Highway).—These signs are erected to warn people to look out for trains. In some States the style and lettering are specified by law. The sign should be 10 to 20 ft. from center of track, and so placed as to be conspicuously visible from the road, but at the same time clear of such bulky traffic as wagon loads of hay, etc. A gong or lamp or other automatic signal may be attached to the post. (See Highway Crossings.) Three common styles are as follows: (1) A horizontal board; (2) Two boards (12 to 20 ins. wide) crossed at 45° to form an X; (3) Four boards framed together in diamond form. The crossing signs of the Baltimore & Ohio Ry. and the Lake Shore & Michigan Southern Ry. are shown in Figs. 103 and 104, the latter having a post built up of planks. The Delaware, Lackawanna & Western Ry. uses a chestnut post 8×8 ins., 16 ft. long, 4 ft. in the ground. The cross arms are of white pine, $1\frac{3}{4}\times12$ ins., 6 ft. 8 ins. long, painted at the ends and spread 21 ins. apart. The post is painted black to a height of 9 ft., and above is white with "Danger" in 5-in. black letters. The letters on the arms are 9 ins. high.

Crossing Signs (Railway).—These are to warn enginemen approaching grade crossings. The Atchison, Topeka & Santa Fé Ry. uses an oak or cedar post carrying two boards crossed at 45°; this faces the train, and is lettered "Railway Crossing." On the post is lettered the distance to the crossing, 2,600 ft. The post is 8×8 ins., 17 ft. long, 6 ft. in the ground, with pine boards $1\frac{3}{4}\times12$ ins., 6 ft. long. It is painted brown, except a white strip for the lettering. The arms are white. The post is set 14 ft. from the rail, on the right-hand side of the track. In some cases an additional sign is used, reading: "Stop, Railway Crossing, 200 Ft." At a crossing protected by interlocking plant this "stop"

sign is not used, but the regular sign may be lettered "Look out for Signals," as in that of the Southern Pacific Ry., Fig. 105. (See Drawbridge Signs.)

Curve Signs.—On lines (or divisions) with numerous curves, it is a good plan to number and mark the curves for convenience in directing the attention of trackmen or enginemen to any particular point. The degree of curve may be marked on the sign for the guidance of trackmen in giving the proper superelevation and in bending rails for renewals, as well as for the guidance of enginemen in handling the brakes. The sign may be a small white board on a stake, close to the ground, or a board 12×18 ins., attached to a telegraph pole at each end of the curve. The New York Central Ry. uses two boards forming a V, attached to a telegraph pole; they are lettered to indicate the mile, the number of curve in that mile, and the degree of curve, thus: "237–A–3° 47′." The Atchison, Topeka & Santa Fé Ry. uses an old boiler tube 4 ft. long, 2½ ft. in the ground. The upper end is flattened for about 12 ins., and the figures (2° 30′) stamped and painted black. The letters are vertical. It is set on the right-hand side (in the direction in which the miles are numbered), being placed opposite the point of curve and 2 ft. from the rail, with the lettered side facing the trains. A curve post is shown in Fig. 106. The curve elevation post of the Pennsylvania Lines, Fig. 107, is set 6 ft. from the rail; it is white with black letters. Roads using transition curves set posts at the point of main curve and point of spiral curve. These resemble clearance posts, and the second has the superelevation marked upon it. The Cincinnati Southern Ry. follows this practice: the first is lettered "E. 0," and the second with the superelevation (to the nearest half-inch). The posts are 2×4½ ins., 3½ ft. long, 1½ ft. in the ground, painted black, and set with the lettered side facing the tangent. (See also Speed Limit Signs.)

Drawbridge Signs.—The Southern Pacific Ry. uses three oval signs, 27×42 ins., in advance of the bridge. All are made of 3-in. plank on posts 6×6 ins., 16 ft. long, set 4 ft. in the ground. The signs are lettered "Drawbridge" at top and bottom, with "1 Mile," "1,000 ft." and "Stop," respectively, in large letters in the middle. A similar arrangement is used for railway crossings.

Flanger Signs.—These are to indicate where the blades of snow plows and flangers are to be raised to clear switches, etc. One style is a 1½-in. black board, 12×24 ins., let flush into a white post, 6×6 ins., with the top 8 ft. from the rail. The board is not lettered. This sign is for temporary use only, and is placed 8 ft. from the track, on the right-hand side, and 50 ft. in advance of the obstruction. Other roads use black with white disks, or yellow with black disks. The Delaware, Lackawanna & Western Ry. uses a post 4×3 ins., 8 ft. long, having at the top a board 8×25½ ins. inclined upwards 1 on 2 on the side away from the track. The post is set 10 ft. from the nearest rail, and is painted black for 3½ ft. The board is black with a 1-in. white border (and back). At the location for the sign, there is set in the ground a 30-in. piece of old rail having bolted to the top a malleable-iron socket just above the surface of the ground. Before winter sets in, the signs are erected, the post being secured to the socket by one bolt. As a rule the flanger signs are taken down and stored in the section tool houses for the summer. In November, the section foremen are notified to have them painted and erected.

Junction Signs.—The Atchison, Topeka & Santa Fé Ry. puts up signs 2,600 ft. from junctions, these being identical in style with its railway crossing signs above described, but lettered "Railway Junction."

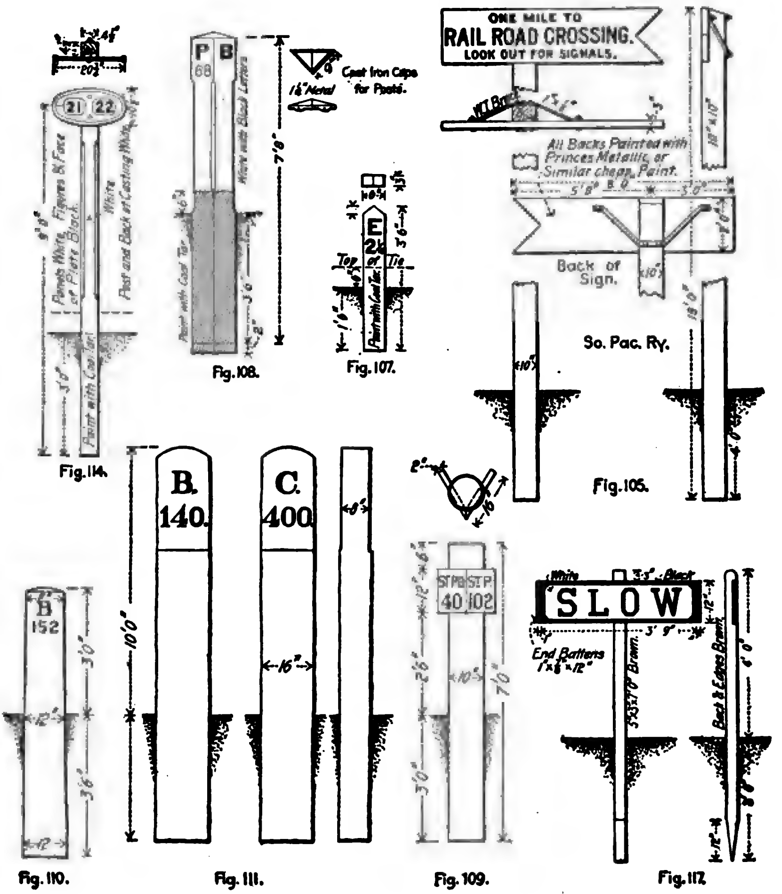
Mile Posts.—These are commonly timber posts, about 10×10 ins., 8 ft. long, set 3 ft. 6 ins. in the ground and 12 ft. from center of track. The post in Fig. 108 is of this style, but the cast-iron cap is an unnecessary expense. The post is set either with one side or one edge towards the track, and may have the distance from (and the name or initial of) one or both of the terminal points painted on opposite sides. The Northern Pacific Ry. sign, Fig. 109, is a post of barked cedar, set on the north side of the track, 8 ft. from the rail. Two boards, 2×12×16 ins., are let into the post at an angle of 60°, and have the names of the terminals of the division marked upon them, with the distances therefrom. The post and board are painted white, with black letters 3¾ ins. high and ⅜-in. thick, and figures ¾×5 ins., with a margin of at least 1 in. The Baltimore & Ohio Ry. uses a 7-ft. post of 2½-in. gas-pipe, with a cast-iron shoe; this is set 3 ft. in a 3½-in. hole, 3½ ft. deep, which is then filled with concrete. On the post is a cast-iron sign 18×8 ins. with semicircular ends; it is ⅜-in. thick, with rim and 5-in. figures on each side raised ⅛-in. A lug at the bottom fits into the pipe and is secured by a rivet. The post is black, with white sign and black letters. Several roads use a sign on the nearest telegraph pole. On the Delaware, Lackawanna & Western Ry. the sign has two 1-in. panels 9×15 ins., set at 90° (45° with the track); on the top is a molding strip 2½ ins. wide to shed the water, and in the angle is a filler strip. Each panel is fastened to the post by two 6-in. lag screws. The sign is 10 ft. above the ground, and painted white. The post is painted white for 7 ft., beginning at 7 ft. above the ground. The half-mile pole is indicated by a 2-ft. white band 6½ ft. from the ground. The Atchison, Topeka & Santa Fé Ry. uses a plate of ⅜-in. boiler iron bent to a V shape to form two panels 7½×20 ins. This is secured to the telegraph pole nearest to the exact distance by means of two lag screws ½×4 ins. It is 12 ft. from the ground on 25-ft. poles (15 ft. on 30-ft. poles). The poles are painted white from 3 ft. above the ground to the sign, which is white with black letters.

Stone mile posts are used by several railways. The Boston & Albany Ry. has square granite posts, Fig. 110, with two sides dressed for 3 ft. from the top, and pene-hammered. The Lake Shore & Michigan Southern Ry. uses 10-ft. posts, Fig. 111. The Maine Central Ry. uses a rough dressed stone slab, 12 ft. long, 20 ins. wide and 8 ins. thick, set 4 ft. in the ground. It has 30 ins. at the top dressed smooth, and painted with three coats of white lead, with black lettering. The post is lettered on both sides, thus: "249 Miles to Vanceboro" on one side, and "2 Miles to Portland" on the other. The New York Central Ry. stone post is 8×16 ins., 9 ft. long, set 4 ft. in the ground on a 12-in. concrete block 30×30 ins. Concrete mile posts used on the Chicago & Eastern Illinois Ry. are 8×8 ins., 8 ft. long, 4½ ft. above ground. The figures and the initial of the terminal are recessed ¼-in. in a black panel 14 ins. high, and there is a ¾-in. horizontal V groove at top and bottom of this panel. The painting of the recessed letters is easily done by unskilled labor. The concrete is a 1:1:2 mixture, and the panel is colored with a facing mixture of ¼ lb. lampblack to 1 qt. of cement in water. The weight is about 500 lbs., and the cost 82 cts.

Premium Signs.—On roads having annual awards for condition of track, a sign is sometimes placed on the best section. A black board with "Premium Section" in gilt or yellow letters is a conspicuous sign for this purpose and may be erected on the section house or on posts at the section house or at a station

on the section. There is no doubt that the men feel proud of such a trophy, and will work hard to prevent another section gang from winning it away from them.

Property Post.—The marking of property lines or right-of-way boundaries should be done very carefully, and permanent monuments should be established. A piece of rail may be used with the web split for about 6 ins., and the head and base bent out to form an inverted T, as shown in Fig. 112. The Lake Shore & Michigan Southern Ry. marks important land corners, etc., with



Track Signs.

a cast-iron post, Fig. 113, having a top cap 2 ins. square. In the center of the cap is a ¼-in. hole ¼-in. deep. A cast-iron post is also used by the Baltimore & Ohio Ry. to mark property corners; it is 3 ft. long, 3 ins. square for 3 ins., with "B. & O. R. R." cast on one side and the date on the other. The body is rectangular, with a 1-in. rib on each corner and tapering from a 4½-in. circular portion above to a 5¾-in. diameter on a flat base 9 ins. diameter. For property line posts, the road uses a wooden post 5½ ft. long, set 3 ft. in the

ground and anchored by a rod or old bolt run through it at 6 ins. from the bottom. The post is of red elm, locust, mulberry, chestnut or cedar; 6 ins. diameter; 2-in. pointed top; barked and tarred below ground; smoothed and painted white above ground. On one side is painted "B. & O. R. R."; on the other side "Property Line" in 5-in. black letters (sidewise). The post is set on the company's side of the line, with one edge on the line; only a sufficient number are used to correctly define the line between corners. The Cincinnati Southern Ry. uses cedar, chestnut or oak posts, or pieces of old telegraph poles, 7 ft. long (3 ft. in the ground), placed at every corner and 500 ft. apart in straight lines. They are painted white and at the top is stenciled in black: "Ry. Co. Right of Way." All corners or angles in the boundaries of station grounds, etc., should be marked by posts, and if these cannot be set at the corners they should be set in the lines running thereto and have the distance plainly painted on the side facing the corner to be marked. These posts may be 8 ft. long, rough below ground, and 5 ins. square for the 3 ft. above ground. The Atchison, Topeka & Santa Fé Ry. uses for station grounds a 5½-ft. piece of old rail, 3 ft. in the ground.

Rail Signs.—The make of rail and date of laying are sometimes marked on stakes set near the track. The Cincinnati Southern Ry. uses a 12-in. cast-iron disk set in the slotted top of a 3×4-in. post, 24 ins. long. This is placed 10 ft. from the center of track.

Section Posts.—These mark the limits of track sections, and should be smaller and less conspicuous than signs to be observed by trainmen. On the Pennsylvania Lines an oval iron sign, $10\frac{1}{2} \times 20\frac{3}{4}$ ins., is bolted to a post (Fig. 114). The plate has two panels sunk $\frac{1}{8}$-in., with raised figures flush with the surface of the plate. The post, panels, and back of casting are white; figures and face of post, black. It is set 7 ft. from the rail. The Southern Pacific Ry. uses iron signs (Fig. 115); the target of old sheet iron, 10 ins. deep, is bent to form two faces 10×15 ins. at right angles to each other, one of these facing the track. At its corner the target is fastened to the top of an old boiler tube by three rivets. This is 15 ft. from the rail. The Atchison, Topeka & Santa Fé Ry. uses only an oak post 2×6 ins., 5 ft. long, set edgewise to the track, 6 ft. from the rail, with the section numbers painted on opposite sides. The Baltimore & Ohio Ry. uses a sign similar to its mile post, but with a 3-in. pipe 8½ ft. long; the cast-iron sign is L-shaped, with two panels $14 \times 12\frac{1}{2}$ ins. The 4-in. letters "Sect." are cast on; and the letters, figures and post are painted black. The Delaware, Lackawanna & Western Ry. also uses a sign similar to its mile signs, with panels $18 \times 11\frac{1}{2}$ ins. Each panel has 7-in. figures and "Sec." in 2-in. letters. The New York Central Ry. uses a target of $\frac{3}{16}$-in. sheet steel, 18×30 ins., on old rail 12 ft. long, 4½ ft. in the ground.

Sidetrack Limit Sign.—On long sidetracks, for use by two trains, a square post like a mile post, but without figures, is placed to mark the middle of the sidetrack, for the guidance of enginemen.

Slow and Stop Signs.—These are used at the approaches to track crossings, drawbridges, etc., and should be painted green (or yellow) and red, respectively, and lettered in white. They are usually either flat posts about 3×12 ins., or large boards on posts. Sometimes the boards are only 4 ft. above the ground, but a greater height is preferable. On the Pennsylvania Lines, these signs are made to conform to the standard position of signals. Thus, one has "Slow" in white letters on an inclined green arm; and the other (Fig. 116) has "Stop"

in white letters on a horizontal red arm. The arms are 8 ins. wide, with 6-in. letters, and point to the right of the track. The posts carry green or red switch lamps. These signs are used where all trains must be under control, or come to a stop, the "Slow" sign being set 2,000 ft. from the danger point, while track crossings have the "Stop" signs at a distance of 300 ft. in each direction. The Baltimore & Ohio Ry. uses similar signs. The post is an old rail, 13 ft. long, set 3 ft. in a 12-in. hole, 3½ ft. deep, fitted with concrete. The arm is of ⅜-in. steel, 3 ft. long, 7 ins. deep at the post and 8 ins. at the end. The letters are

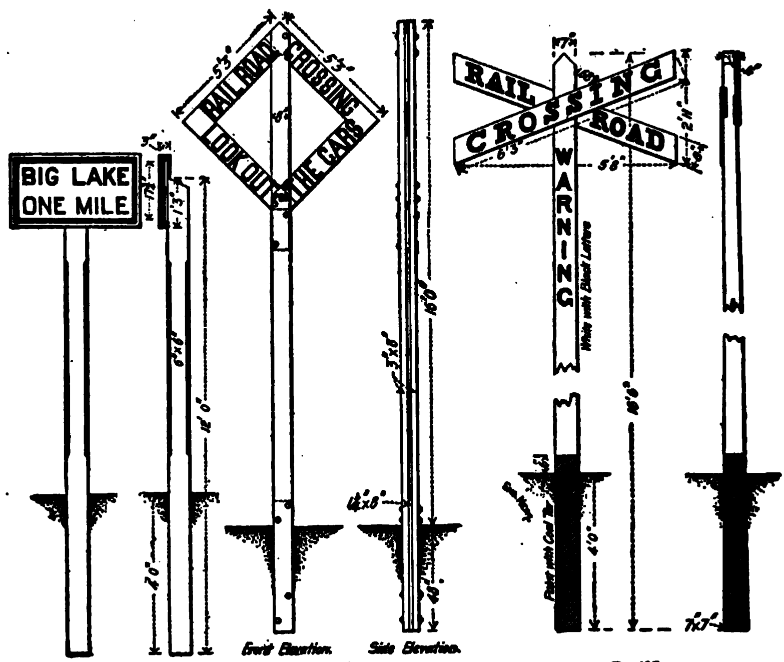


Fig. 113. Fig. 104. Fig. 105.

Track Signs.

cut out, and the end of the "slow" sign has a 3½-ft. arm with forked end. At the opposite side of the post is a bracket for a standard switch lamp. The colors are red and green, or red and yellow on the Baltimore & Ohio Southwestern Ry. The "slow" post is set 200 ft. from the point where all trains must be under full control, and the "stop" post at the point where they must come to a stop (200 ft. from a crossing). The post is 7 ft. 2 ins. from the gage side of the rail. The Delaware, Lackawanna & Western Ry. uses a post 6×6 to 4×4 ins., 8 ft. long, 6 ft. above ground; a 1-in. board sign, 15×31 ins. (with semicircular ends), is set 4 ins. below the top. The letters are 8 ins. high. The sign is white with black letters; the post is white for "stop" and yellow for "slow" signs. The "slow" board of the Atchison, Topeka & Santa Fé Ry. is shown in Fig. 117. This is set 8 ft. from the rail, at least 3,000 ft. distant. The "stop" post is like a station sign, and is set 200 ft. from the crossing. A "stop" sign is shown in Fig. 118. Where only freight trains are required to

be under control, a post 3×10 ins. is used, 6 ft. high above ground, painted green, with "F. S." in 8-in. white letters.

Speed Limit Signs.—Where bridge, culvert or track repairs are in progress on the New York Central Ry. a sign "Reduce Speed to — Miles per Hour" is set 3,000 ft. in advance of the working limit, which is marked by a regular "slow" sign. The former is a board sign 15×36 ins.; green, with white letters and border. A pocket receives a sheet-iron tablet lettered with the speed allowed, and there is a hook for a green lamp. The top of the sign is 10 ft. 9 ins. above the rail. At a train length beyond the other end of the working limit is a similar but white sign lettered "Resume Speed," in black. Where these signs must be set between the tracks, they are 12×18 ins., with the bottom 6 ins. above the rail. When the work will occupy less than four days a green flag (or lamp) is put 3,000 ft. in advance of the work and a white flag (or lamp) 30 ft. beyond.

For sharp curves, a sign 3×4 ins. on a 15-ft. rail (5 ft. in the ground) is set 2,500 ft. from the curve and facing the traffic. This is painted green, lettered in white with the speed, name of curve, speed allowed, and track indicated: "Speed Limit; —Curve; —Miles; Track No.—." The Southern Pacific Ry. sign to reduce speed for track work, etc., is a yellow flag, 19 rails or 15 telegraph poles in advance. The Cincinnati Southern Ry. uses a board sign 36×16 ins., 6 ft. above the rail, on a 6×6-in. post. At the point where speed is to be reduced, the board is green with "Speed 15" in white letters. At the other end of the section the sign is white, with "Resume Speed" in black letters. At bridges, the speed sign is a diamond-shaped cast-iron plate 30×18 ins., on a post (as above); it is painted green, lettered in white, and on the top of the post is a stand for a lamp (green).

Station Signs.—A sign is usually placed one mile each way from a station, and whistle posts are also usually placed half a mile from the station, directing the engineman to whistle for the station. The distance should be measured from the outer switch of the station yard, or from the yard limits. A common style is shown in Fig. 119. This is set 10 ft. from the rail. The board is 10×10 ins., 1 in. thick, with a frame 1×3 ins., and a 1-in. molding strip. The post and board are white, with black letters, frame and molding. The letters and figures are 5 ins. high, 1½ ins. thick, with a 2-in. margin, and 3½ ins. between lines. The Atchison, Topeka & Santa Fé Ry. uses an oak post 3×10 ins., 11 ft. long, set 5 ft. in the ground. This is set on the right-hand side, 6 ft. from the rail and 2,600 ft. from the headblock farthest from the station. It is lettered vertically. The Delaware, Lackawanna & Western Ry. uses a 12-in. board (with 6-in. letters) 3 ft. long up to 9 letters, or 4 ft. for a longer name.

Station Name Boards.—These should be large, boldly lettered and conspicuously placed. No advertising signs should be placed near them, and no advertising signs of similar style should be allowed. If placed on the platforms they should be set back from the track, and have lamps especially placed to illuminate them, but many roads place them on the ends of the building. It is a good plan to have glass name slips in the windows of the agent's office, waiting room, etc. The sign should be not less than 18 ins. wide, the length varying with the name. White or yellow block letters on a black or dark-blue ground are very prominent, while black on white or buff is very generally used. The station sign of the Atchison, Topeka & Santa Fé Ry. is attached to each end of the building, with the bottom 8 ft. above the platform wherever practicable. Where

there is no station building, the sign is placed on a 10-ft. post, midway between the headblocks of siding, and 20 ft. from the main track. The board is $\frac{7}{8}\times14\frac{3}{4}$ ins. with a frame $1\frac{1}{8}\times1\frac{1}{2}$ ins.; it is white, with black frame and 12-in. black letters. Many roads put the distance to terminal points on the signs. The Southern Pacific Ry. uses a board 2×14 ins., with $7\frac{1}{2}$-in. letters. On the ends are lettered "To New Orleans — Miles" and "To San Francisco — Miles," in 2-in. letters. Beneath the name is "Elevation — Ft." in 2-in. red letters. The Cincinnati Southern Ry. uses a board 28 ins. wide with beveled edges;

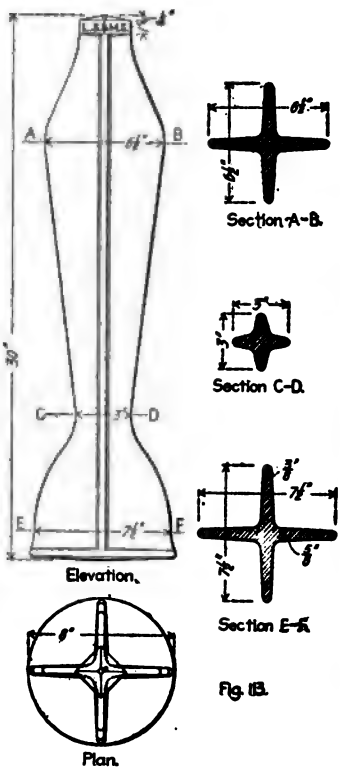


Fig. 113.—Property Monument; Lake Shore & Michigan Southern Ry.

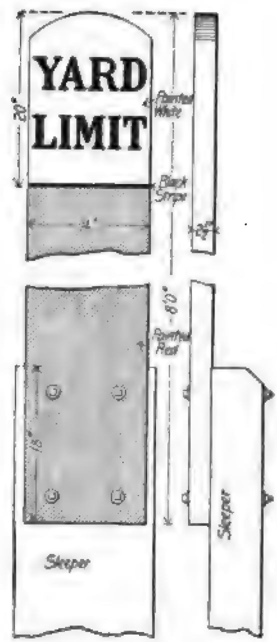


Fig. 123.—Yard Limit Sign; Maine Central Ry.

the shaded block letters are 12 ins. wide, with $1\frac{5}{8}$-in. lines and $\frac{3}{4}$-in. shade lines. At each end is a 13-in. panel for the distances from Cincinnati and Chattanooga respectively. The board is black, with gilt letters and edge. For the less important stations a 12-in. board with yellow letters is used. It is an excellent plan to make the name of the station in large clear letters of white stones, shells, flowers, etc., on a turfed strip or a leveled surface of cinders just beyond the platforms.

Warning Signs.—The Baltimore & Ohio Ry. uses a trespassing sign in the form of a cast-iron panel $27\frac{1}{2}\times10\frac{1}{2}$ ins., with socket to fit into a 3-in. pipe post 8 ft. long (5 ft. above ground). This is lettered "Warning" in 4-in. letters,

and beneath is "Trespassing Upon Railway Property is Forbidden." The Cincinnati Southern Ry. uses a sign 34½×18 ins., lettered "Caution. Do Not Walk or Trespass on the Railway." Also a board 25 ins. square: "Not a Public Crossing—All Persons are Warned not to Trespass." These are white, with black letters; and are set 8 ft. high on posts 15 ft. from the rail.

Water Tank Signs.—At stations having water tanks for the engines, the words "Water Tank" may be painted on the one-mile station sign, while for tanks between stations a special board sign with "Water Tank, One Mile" (or "½ Mile"), may be put up. The Cincinnati Southern Ry. uses a cast-iron diamond-shaped sign with sides 3 ft. long and 8 ins. wide, with 6-in. letters. This is 9 ft. from and 10 ft. above the rail. The ends of track tanks are usually marked by green targets or arms, on posts carrying green switch lamps at night. This is to indicate to firemen when to lower and raise the tender scoop, the latter signal being placed about 100 ft. from the end of the tank.

Whistle and Ring Signs.—These are usually set ¼-mile on each side of the road crossings and ½-mile or 1 mile from stations, placed on the engineman's side of the track. They may be flat posts, 10×4 ins., set with the edge to the track and having the top cut to a point or rounded. Fig. 121 shows the Baltimore & Ohio Ry. post. Square posts, 8×8 ins., are also used. The length is from 8 to 12 ft., with 5 to 8 ft. above ground, the higher ones being used where deep snows occur. The posts are usually white, with a large black R or W (or both) 6½ ins. high, the sides and back being sometimes painted light blue, so as not to be conspicuous. In some cases the face is cobalt blue with white letters, or brown with a white panel and black letters. The Delaware, Lackawanna & Western Ry. uses a cast-iron sign 14½ ins. diameter, having a lug fitted to the slotted top of a 10-ft. post; this is ½-in. thick, with 1-in. rim and ¾-in. letters 8 ins. high. A sign made from scrap is used by the Southern Pacific Ry., Fig. 122. It is painted white, with black letters, and is set 1,320 ft. from the crossing or 2,700 ft. from the outer switch of a station. Where the former comes within 500 ft. of the latter, the latter only is used. The X on this sign is to indicate that it is a crossing sign, and some roads put "S. W." on the station whistle posts. For a post 10 or 12 ins. wide, the letters should be about 9 ins. high and 8 ins. wide, with lines 1½ ins. thick; plain block letters should be used. "Whistle and Ring" signs (lettered W. R.) are used at places where it is necessary to give warning to track and bridge men of the approach of trains; these should be 1,000 ft. distant from the point to be warned. Concrete posts are used on the Lake Shore & Michigan Southern Ry.

Yard Limit Signs.—These denote the limits covered by the yard gangs, and to which switching engines work. Trains are usually required to be under control entering the yard, unless the track is plainly seen to be clear. (See Chapter 12.) The Pennsylvania Lines use an oval cast-iron sign, 33½×20 ins., 4 ft. 6 ins. above the ties; it is painted green, with white letters. A similar sign on the Baltimore & Ohio Ry. is set on a pipe post, 9 ft. above ground, and is white with black letters. A green (or yellow) lamp is shown at night. The Southern Pacific Ry. uses a Y-shaped sign, with two 9-in. boards 3½ ft. long set at 45° upon a post. The Maine Central Ry. sign is shown in Fig. 123. In some cases the station name is painted on these signs.

CHAPTER 12.—WATER AND COALING STATIONS AND OTHER TRACK ACCESSORIES.

Water Supply and Water Tanks.

The construction and maintenance of all structures and equipment pertaining to water supply frequently come more or less under the charge of the track department. The supply is usually taken from wells or streams, and where the supply is scarce and uncertain or where a large quantity is required, storage reservoirs are sometimes built, or dams to form natural reservoirs. Where the supply is scarce it may be necessary to haul water in tank cars or to pump it long distances to supply the station tanks, and both methods are in use on parts of the Eastern Ry. of New Mexico. The El Paso & Southwestern Ry. is distributing a good quality of water along its road for about 130 miles by a pipe line, the high cost of this being warranted by the extremely bad quality of the local waters.

The water is usually pumped direct to tanks at the stations. The most common form of tank is of wood (cypress, cedar or pine), with vertical staves 3 or 4 ins. thick, hooped with iron bands. Iron bands are in general more satisfactory than steel, the latter corroding much more rapidly. They are usually from ½-in. to ¾-in. thick and from 3 to 6 ins. wide. Round rods are occasionally used instead of flat bands, giving better opportunity for inspection, and less liability of concealed corrosion which might result in the bursting of a tank. There is liability, however, of their crushing or bruising the wood unless extra care is taken in tightening them. A very general size of tank is 16 ft. high and 24 ft. diameter, with a capacity of 50,000 gals., but the tendency is to use tanks of from 75,000 to 100,000 gals., even at ordinary water stations. The tank is supported on a trestle tower of timber or steel, or upon a masonry tower. Such a construction is shown in Fig. 124, but the tower should be considerably higher to give a greater rate of flow in discharging. Steel tanks are also used, and there should not be much trouble from corrosion if they are kept full and the outside is kept well painted. The level of water in the tanks is shown by a float connected to a ball sliding on a staff above the roof or to a pointer moving on a graduated scale on the side of the tank. A float may also operate an inlet valve or a pump starting device, so as to keep the tank full.

Steel standpipes are used to some extent, and generally in connection with water columns. The Chicago, Rock Island & Pacific Ry. has 24-ft. steel standpipes with heights of 31½ ft., 47 ft., and 62 ft. for capacities of 60,000, 115,000, and 165,000 gals. They are built of rings of 8-ft. plate, and have flat tops. In the concrete foundation is a chamber with the valves and connections for the 6-in. supply, 12-in. outlet, and 6-in. overflow pipes. There is also a blowout with an 8-in. tank valve, and a pipe to a drain of 8-in. sewer pipe. The standpipe is, if possible, put at an elevation of not more than 15 ft. above the track, and a 12-in. pipe is led to the 10-in. water column, which is set 350 ft. from the station on main lines or 200 ft. on branches. The water column is 8½ ft. from the track, c. to c.; the spout is 12 ft. above the rails, the flexible joint allowing a movement of 1 ft. above or below this position. The concrete pit under the column contains a 10-in. gate valve and a 12-in.

to 10-in. reducer or branch pipe from the 12-in. main. This pit is $4\frac{1}{2}\times8$ ft., and the depth from top of rail to center of branch pipe is 4 ft. in warm climates or $6\frac{1}{2}$ ft. in cold climates. The Atchison, Topeka & Santa Fé Ry.

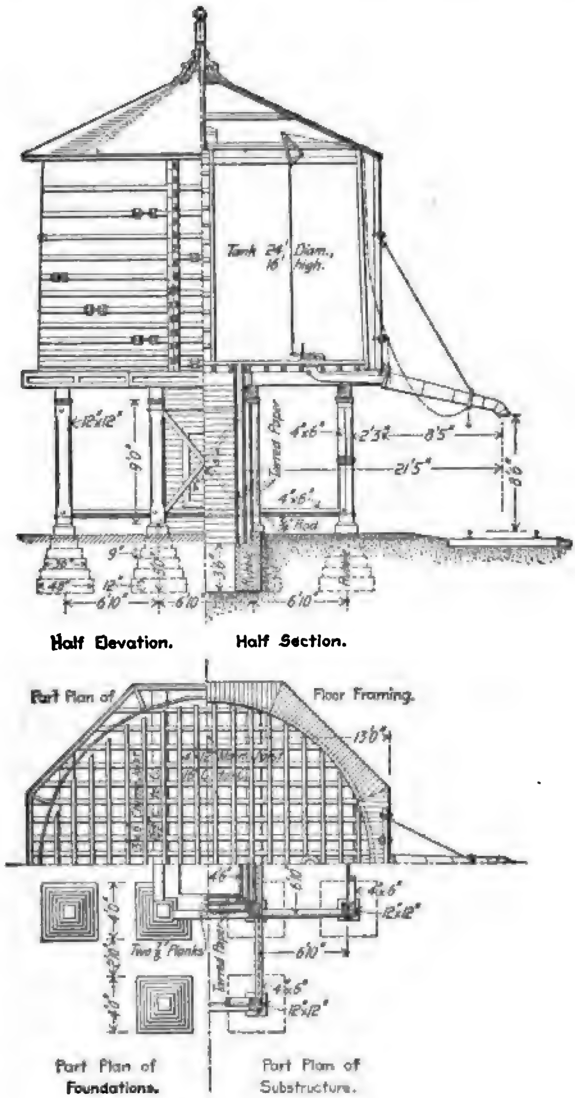


Fig. 124.—Water Tank for Supplying Locomotives.

has standpipes 24 ft. diameter, 40 and 60 ft. high; the capacities are 96,000 and 202,000 gals., or 57,700 and 163,800 gals. available above the spout for supplying engines, which is 12 ft. above the rails. A combination tank and standpipe has the lower portion of smaller diameter, steel columns supporting

the sides of the tank proper, which has a hemispherical bottom. The central portion is of sufficient diameter to insure safety from freezing, even without a frost-proof covering; it is fitted with a valve for blowing out the water and sediment in this portion without emptying the tank. Where the tank stands at the level of the track, this design may cost less than a standpipe of the same available capacity. The saving is due to lighter foundations and less steel plating, even with allowance for the cost of the columns.

Trouble from freezing of tanks at wayside water stations varies greatly, even on roads in the same district. It is affected largely by the character of the water, the quantity of water drawn from the tank, and the degree of care given to the tank. This last is one of the most important conditions. A road giving particular attention to its tanks may have little trouble, while another road which gives them little attention may find it necessary to try sheathing and heating. The protection usually consists of top and bottom air spaces with double sheathing (side protection is rarely found necessary). A stove pipe may be carried through the tank, or a steam coil (for live or exhaust steam) may be set within it. The water pipes below the tank are usually enclosed in a wooden box or shaft, the walls of which are formed with two or more air spaces. One of these spaces may be packed with sawdust. A stove or steam pipe may be placed inside the boxing. On the Canadian Pacific Ry., the tank and its supports are completely housed in a tower 28½ ft. diameter, leaving room for access to the bands of the 24-ft. tank. A stove with 8-in. pipe is placed beneath the tank. This arrangement provides ample protection, and with no ice in the tank there is no trouble from clogging of the valves. At tanks and water columns, provision must be made to prevent leakage, or in winter there may be an accumulation of ice over the rails, which may perhaps cause a derailment. During extremely cold weather the section foreman is often called upon (through the roadmaster) to furnish a man to look after the water stations. All the pumps, pipe connections, valves, tanks and other equipment, should be thoroughly examined at least once a year, and a special examination made before winter to see that all outdoor work is tight and properly protected against freezing.

Where engines take water directly from the tank, a horizontal pipe from the bottom leads to a hinged spout which may be let down to enter the manhole of the tender, but is counterweighted to stand vertical. It is pulled down by a chain within reach of the fireman standing on the tender, who also operates the valve by means of a chain or lever, or the valve may be operated from a handwheel on a stand on the ground. This system of supply, with a wooden tank on a wooden tower, is shown in Fig. 124. When the tank cannot be placed close to the engine track, or where engines on several tracks have to be supplied, the usual practice is to lay pipes to water columns beside or between the tracks. The water column consists of a vertical stationary pipe, with a horizontal swinging arm, which should be so mounted as to lie normally parallel with the track, its end being over a catch basin with grated top. The arm may be hinged so as to reach down to the tender, or it may have a leather hose or adjustable vertical spout on the end. The position of the column in relation to the track and catch basin is shown in Fig. 125. At large water stations a pipe may be carried across the railway, and fitted with hinged spouts over the tracks.

Many water stations have too slow a discharge from the tanks, so that trains

are delayed in taking water. The Chicago & Alton Ry. puts 90,000-gal. tanks (18×30 ft.) 20 ft. above the rails, with 14-in. mains to 12-in. water columns, delivering 4,000 gals. per minute (or 4,500 gals. with tanks elevated 25 ft.). Where the tanks have spouts, these are served by 8-in. outlet pipes. Some of the tanks are two miles from the pump houses. The Chicago, Milwaukee & St. Paul Ry. uses wooden tanks of 50,000 gals. capacity and steel tanks of from 80,000 to 100,000 gals. The height from rail to bottom of tank is 16 ft.,

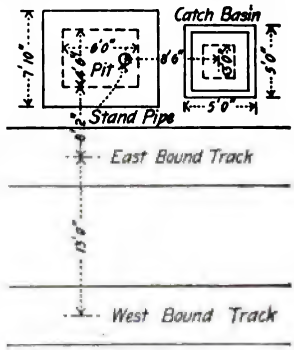


Fig. 125.—Location of Water Column.

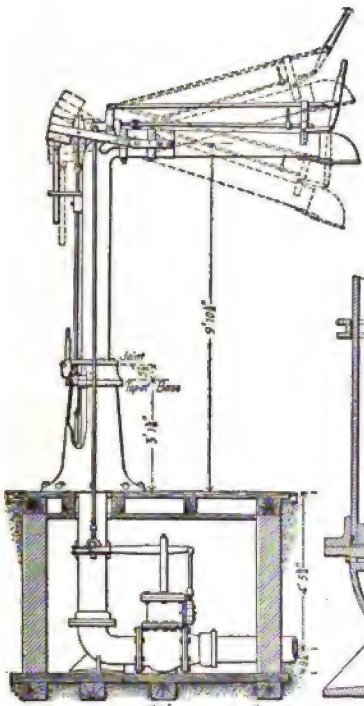
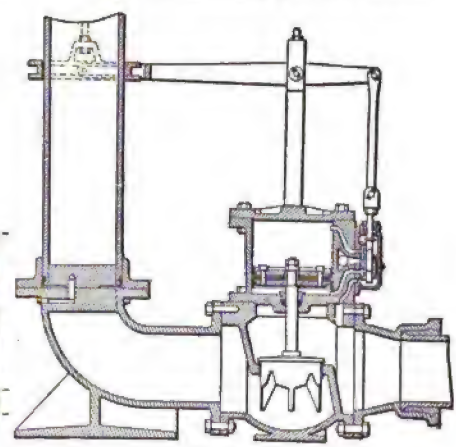



Fig. 126.—Water Column and Hydraulic Valve.

except that those serving water columns are from 22 to 26 ft. high, according to the distance (50 ft. to several hundred feet) or other local conditions. The pipes are 8 ins. to the spout, and 10 ins. to 10-in. water columns. As a rule, however, the main should be somewhat larger than the water column, a 12-in. or 14-in. main to a 10-in. or 12-in. column. The Pittsburg & Lake Erie Ry. is using steel tanks of 150,000 to 500,000 gals. capacity, and these are replacing the older 50,000-gal. wooden tanks on steel substructures. The height is 21 ft. from rail to bottom of tank. An 8-in. pipe runs from pump house to tank, and 12-in. mains to 10-in. water columns are the standard, delivering water to the tenders at about 2,000 gallons per minute. The Canadian Pacific Ry.

uses 40,000-gal. tanks 16×24 ft. (23 ft. at top), having the bottom from 20 to 40 ft. above the rails, while the heel of the spout is 13½ ft. from the rails.

In the water column which is shown in Fig. 126, the pipe is supported by a high base casting, and is automatically latched when the arm is parallel with the tracks. The latch may be secured with a switch lock. The spout has a flexible joint of vulcanized rubber, or of metallic construction in large sizes where the force of the water would make it difficult to hold the spout down in the manhole. The weight of the spout is counterbalanced. The valve may be operated by a handwheel on the end of the spout, to prevent shutting off the water too suddenly. A relief valve may be provided where the pressure is heavy, or an air cushion to absorb the shock due to water hammer in case the valve is closed too quickly. In Fig. 126 the main valve is operated by the water pressure and not by hand. The piston in the hydraulic cylinder over the valve has an area considerably larger than that of the valve, and the flow of water to and from the cylinder is controlled by a slide valve operated from the lever on the end of the spout. The exhaust is controlled by a small stop cock which can be set to secure slow closing of the valve if required.

The pumps supplying the tanks with water may be driven by wind wheels, electric motors, or steam or gasoline engines. The last are in many respects preferable to and more economical than steam; the economy varies with the cost of coal and is largely in the reduced labor for attendance and the lower cost of fuel. At stations the agent can attend to the gasoline plant. The Canadian Northern Ry. uses 5-HP. gasoline engines geared to pumps of 6,000 gals. per hour. An electric plant for a 50,000-gal. tank has two centrifugal pumps, each driven by a 7½-HP. motor, and with a 2½-in. discharge to a 4-in. main. The controller is operated automatically by the float. Railway windmills have wheels from 10 to 25 ft. diameter, running at 50 to 30 revolutions per minute and operating pumps of 2×4 ins. to 10×24 ins. The steam pumps usually have a stroke of 6 to 18 ins., and double-acting pumps have twice the capacity of single-acting pumps. Vertical well pumps 4×12 ins. at 100 revolutions per minute deliver 64 gals. per minute; pumps 6×18 at 80 revolutions deliver 175 gals. The capacities of some windmill and steam pumps are given in Table No. 15. The first four steam pumps are single-cylinder pumps making 100 revolutions per minute. The others are duplex pumps, the delivery per stroke being for each cylinder, while the delivery per minute is for both cylinders, making 50 to 100 strokes per minute. All the steam pumps are of 12 ins. stroke.

TABLE NO. 15.—PUMPS FOR WATER STATIONS.

Windmill Pumps.

Inches.	Gallons.	Inches.	Gallons.	Inches.	Gallons.	Inches.	Gallons.
2 ×4	0.052	3 ×6	0.178	4× 8	0.422	6×15	1.814
2½×5	0.102	3½×7	0.284	5×10	0.835	10×24	8.040

Steam Pumps.

Cylinders.		Delivery per stroke.	Delivery per minute.	Pipe.			
Steam.	Water.	Gallons.	Gallons.	Steam.	Exhaust.	Suction.	Discharge.
6	6	1.47	147	¾	1	4	4
7½	7½	1.91	191	1	1¼	5	5
8	10	4.08	408	1	1¼	6	6
10	12	5.87	587	1½	1½	8	6
6	5	1.02	100– 200	1	1½	5	4
8	7	2.00	200– 400	1½	1½	6	5
10	8½	3.00	300– 600	2	1½	6	5
12	14	8.00	800–1600	2	2½	12	10

Track Tanks.

In order to enable trains to make long runs without stopping, means must be provided for supplying the engine tenders with water, and for this purpose long shallow tanks are laid upon the ties. A vertical pipe with its top terminating in an elbow is placed in the tender tank, and extends through the bottom. Its lower end is fitted with an adjustable hinged "scoop" which is lowered about 3 ins. into the water while the engine is running over the tank. The speed of the engine forces the water up the pipe into the tender. Water can be taken at 60 miles an hour, although it is better not to exceed 40 miles. The scoop is operated by the fireman by means of a lever or a compressed-air cylinder and is counterbalanced against the water pressure. The track tanks are usually from 25 to 30 miles apart, and are supplied by direct pumping or from elevated water tanks. This system was invented in England by Mr. J. Ramsbottom in 1861.

The track tanks of the Michigan Central Ry., Fig. 127, are about 1,400 ft. long, 19 ins. wide and 7 ins. deep. They are of $\frac{3}{16}$-in. steel, with a half-round

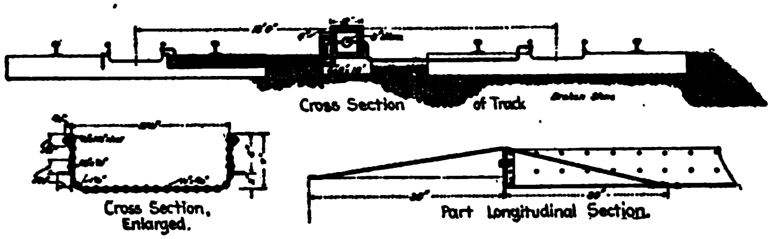


Fig. 127.—Track Tanks; Michigan Central Ry.

$1\frac{1}{2}$-in. stiffening bar along the upper edges. Steel angles $1\frac{3}{4}\times1\frac{3}{4}$ ins. support them on the ties, which are 8×8 ins., 8 ft. long, boxed out to fit the bottom of the tank. Water is supplied by a pipe entering at the most convenient point through a box riveted to the bottom of the tank, from which it flows through a 5-in. opening. Branch pipes to admit steam to prevent freezing in winter are placed about 40 ft. apart along the entire length of the tank, and the construction of the $\frac{1}{2}$-in. brass nozzle is such as to throw the jet of steam downward. With very cold weather, however, steam jets are not sufficient to prevent the formation of ice, and on the Chicago, Milwaukee & St. Paul Ry. a circulating system has been introduced. At the mid-length of the tank a 5-in. pipe enters the bottom, and forms the suction pipe of a steam pump. From the pump the water is forced into an 8-in. return pipe, into which is led a 1-in. steam pipe from the boiler. From the end of the return pipe two 3-in. pipes are laid to the ends of the tank, the water being discharged behind the inclined iron apron which raises the scoop in leaving the tank if the fireman has not raised it in time. The pipes are all laid in square boxes of 2-in. plank. This combination of heating and circulation has proved successful at 20° F. Men must be employed to clean the tanks and clear the rails from ice formed by the spray and spilling of water. Some roads put lateral supply pipes 300 ft. apart, with automatic valves and floats. The track tanks of the New York Central Ry. are $23\frac{3}{8}\times7$ ins., built of $\frac{3}{16}$-in. plates, and having along each side a 5-in. steel channel whose lower flange rests on the ties, which are boxed out 2 ins.

The Baltimore & Ohio Ry. in 1890 put on fast trains between Philadelphia and Baltimore (1 hour 47 mins. for 92 miles with heavy trains), and two track tanks were put in, dividing the distance into three sections of about 30 miles each. The troughs being 1,200 ft. long, it was necessary to make the track level for that distance, running off easily at each end to regular grade. This work was done by the regular track force. The hewed ties were replaced with sawed ties of white oak, 8×9 ins., boxed $1\frac{1}{2}$×19 ins. to receive the tanks. The tanks are 6 ins. deep, 19 ins. wide, made of $\frac{3}{16}$-in. steel sheets, 15 ft. long, with a shelf angle $1\frac{1}{2}\times1\frac{1}{4}$ ins., riveted to each side, $1\frac{1}{2}$ ins. from the bottom. These rest upon the ties, and the tanks are fastened by ordinary track spikes, the heads of which catch on the angles. This allows the tanks to expand or contract, but they are fastened firmly at the centers. They were made in 30-ft. sections in the shop. In laying, each joint was red-leaded, and cold-riveted with $\frac{3}{4}$-in. rivets, 20 to the joint. At each end is placed an inclined plane, with a total length of 13 ft. 8 ins.; the inner end of this is riveted to the bottom of the trough and the outer end fastened to the tie by means of rail spikes driven at the edge of the plate, with heads of spikes resting thereon, thus allowing for expansion of the trough. The object of this plane is to raise the scoop on the tender in case the fireman should fail to raise it, thus preventing damage either to scoop or tank.

At each track tank the water is pumped into a 50,000-gal. tank 28 ft. above the track, and this is always kept full. An 8-in. cast-iron pipe is connected to the elevated tanks, and run to a point at or near the pump, where it is reduced to 6 ins. At this point is placed a 6-in. gate valve. The supply pipe, running directly to the trough, branches off to three points by means of tees, reduced to $3\frac{1}{2}$ ins at the point of leaving the valve. A 12-in. main with 6-in. outlets to the track tank would be better, enabling the tank to be filled more rapidly. Two of the branches are connected to the trough at 200 ft. from the ends and the third is connected to it at the center. At each of these connections there is built a pit the full width of the track, about 3 ft. wide and $3\frac{1}{2}$ ft. deep, with the side and end walls of masonry. The top is covered with 2-in. plank, and the bottom drained to one side. Into these pits the pipe is run, and it is connected to the trough by means of a $3\frac{1}{2}$-in. pipe flange, nipple and metal expansion joint. These expansion joints were made in 1890, and were still in good condition in 1907, the only repairs required having been slight repairs to the packing. Some roads have used a rubber hose in place of an expansion joint. A $3\frac{1}{2}$-in. globe valve at the pit serves to empty the troughs for cleaning or repairing.

In order to keep the troughs free from ice during cold weather, a $2\frac{1}{2}$-in. pipe connected to the steam dome on the boiler in the pumping station is carried to the center of the tracks on double track, or to the ends of the ties on single track. There the pipe is reduced to 2 ins., and run to a point 5 ft. from the end of the trough. On this pipe at intervals of 45 ft. is placed a cross, from which a 1-in. pipe is carried to the troughs. This connection is made with a nipple of extra strong pipe, 3 ins. long, tapped out at one end and plugged, with a $\frac{1}{8}$-in. hole, inclined downward. Immediately back of this nipple is placed a 1-in. check valve to prevent the back flow of water when steam is turned off. The 2-in. pipe is drained from both ends with a drain cock placed at the lowest point. Expansion joints are placed at intervals of 200 ft. All steam pipe should be boxed in and packed with mineral wool or clothed with

pipe covering, to reduce the condensation. The pressure of steam necessary to prevent freezing in the coldest weather was found to be about 80 lbs. During the warm months, when steam is needed for pumping only, an upright boiler of 25 HP. is used. During the cold months, when it is necessary to have steam constantly in the troughs, an old locomotive boiler of about 80 HP. is used at each station. This system of heating has been in use for ten years, and has been tested by extremely cold weather, but none of the troughs have been frozen. At these, as well as at all other water stations on the Philadelphia Division, a pump of 260 gals. capacity per minute is used.

At the approach end is placed a signal (similar to a high switchstand) to notify enginemen and firemen where to lower the scoop. At 100 ft. from the far end is placed a similar signal to warn the fireman to raise the scoop. As already mentioned, 6-in. valves are placed in connection with the supply pipe at or near the pump house. Over these valves is built a small valve house, with its floor about on a level with the track. After an engine has taken water, these valves are opened and water is allowed to run into the trough for from four to six minutes. At first there was considerable complaint that the troughs were often not more than two-thirds full. On investigation it was found that a considerable amount of water was thrown out by the current of air caused by the passage of freight trains. The pumpmen were, therefore, instructed to inspect the troughs five minutes before schedule time of trains; to see that they were properly filled; and to remain in the valve house from that time until after the train passed. It has been suggested that a float valve might be installed to allow the troughs to be filled automatically, as at some other track tanks, but as the pumpmen are required to patrol the troughs regularly and see that they are filled between all trains, it is not considered that this would be any advantage, as it might make the pumpmen careless.

Water Softening.

The quality of the supply is a very important matter, affecting the life of the boilers and the steaming capacity of the engines, and, therefore, the expense of operating and maintaining the motive power. It is rarely given much thought in location, however, the only consideration then being to get water, regardless of quality. Good boiler water is rather exceptional, and if it is not obtainable from natural sources, then the water should be chemically treated before it is delivered to the engines. The character of the water varies so much that each supply must be examined and the proper treatment prescribed, some simple means being adopted by which the proper proportions of chemicals in each case can be used by the man in charge of the station. The matter must be not left entirely in his hands, however, but must be under the regular supervision of a competent chemist in order to insure efficiency and economy. The treatment will effect great economy in reducing the cleaning and repairing of locomotive boilers, increasing their life and the time for which the engine will run before going to the shops. It will also reduce the engine failures on the road. The economic results are so evident that many railways have had comprehensive investigations made of the water supplies along their lines and the treatment required at each point, and have gone largely into the establishment of water-softening plants. On the eastern division of the El Paso & Southwestern Ry., however, the well waters are so bad that even

treatment cannot make them satisfactory, and it has been found economical to develop a supply of good water in the mountains and to distribute this along the railway by a pipe line for about 130 miles.

The troubles due to bad water are of three kinds: Scaling, corrosion and foaming. The first is the principal trouble, due to hard water with scale-producing contents. The principal ingredients are carbonates and sulphates of both lime and magnesia. The carbonates form only soft scale or mud, but a very slight percentage of sulphate will cause a hard scale, and scaling will occur as long as there is the slightest amount of sulphate of lime. The chemicals generally used are soda-ash (carbonate of soda) and slaked lime, separately or in combination. The former has a tendency to increase the foaming properties of the water. For this reason barium hydrate has been tried as a substitute, but it has no advantage over the lime in removing the carbonates. Tri-sodium phosphate has also been tried, but both of these are too expensive for ordinary use. Besides the scale-forming solids, water usually contains free carbonic acid, and sometimes sulphuric acid; these tend to cause corrosion in the boiler and must be neutralized. Alkaline water is also met with in certain districts, but it is rarely advisable to treat it with soda-ash if it contains 50 grains per gallon, as it will give trouble from foaming, even though it does not form scale. As a general thing it will be beneficial to treat water containing more than 15 grains of hardening matter per gallon of water, or even less if there is a large proportion of sulphate of lime. There are numerous water-softening systems in use, but the chemical principle is the same in all cases, and the differences are in the mechanical treatment for mixing and measuring the solutions, and treating the water. It is essential that the chemical should be thoroughly mixed with the water, and that ample time should be given for the chemical reaction and for sedimentation. The time should generally be from three to four hours. The time increases with the badness of the water and its low temperature; higher temperature facilitates the settlement. As the water enters the apparatus it is dosed with the lime and soda-ash solutions, mixed and agitated, and then remains quiescent in a tank of sufficient capacity to give ample time for sedimentation. In the continuous system, the treated water has a slow rate of flow and is discharged through an overflow pipe into the top of the railway tank. In the intermittent system, it is delivered to settling tanks and thence pumped to the railway tank as required. Electric treatment has been tried, but is too expensive for general use.

Coaling Stations.

At points where locomotives take coal, there should be ample provision for coal storage (for about three days' supply). Storing the coal in cars is expensive and keeps cars out of proper service. The coal may be handled and delivered to the tenders in various ways, according to the location, the storage system and the number of engines to be supplied daily. The demand for saving in labor and time has led to a general use of mechanical appliances. The coal should have as little handling and as little direct drop as possible, to reduce expense and the breaking up of the coal. The supply should be weighed, but this is not generally done. In the large plant of the Terminal Ry. at St. Louis, the 15-ton elevated hoppers, or pockets, are supported on

scales. In other cases the pockets are of 100 tons capacity, each connected to a scale. The coal is often stored in piles on the ground, and removed as required to the coaling plant by a conveyor system. Where no room is available for this, it is usually stored in elevated bins for supplying the pockets, or in the pockets themselves. It may be delivered to the engine tenders in various ways. (1) Hand shoveling from a coal stage; (2) Buckets handled by a locomotive crane on the ground or on a coaling stage; (3) Grab buckets handled by a traveling crane; (4) Dump cars running on a coaling stage beside or above the track; (5) Elevated chutes. These general plans admit of various combinations and modifications. The coal may be shoveled from gondola cars or dropped from hopper-bottom cars onto the storage space on the ground or at the back of the coaling platform. It may be then either shoveled directly into the tender, or into buckets or cars which are wheeled to the crane or to the dumping track on the edge of the platform.

The most usual plan is to deliver the coal from elevated chutes, which may be on a bridge over several tracks or in the side of a shed with a coaling track on one or both sides. In some cases small cars are wheeled by hand from the coal pile and dumped at the chutes, but the more common plan is to have bins or coal pockets behind the chutes. These pockets may be filled directly from coal cars run into the coaling station. The approach grade may be 5 or 6% if operated by locomotives, or 20% if a cable and hoisting engine are used. The cable may be hitched to the car, or to a dummy car or "barney" which runs on a narrow gage track between the main rails and normally stands in a pit between the latter, from which a steep grade brings it to the level of the main track. When the coal cars are pushed beyond this pit the "barney" car is hauled up and pushes the coal cars before it. The pockets may also be filled from the storage piles or elevated bins by a bucket and cableway, or by a belt or endless bucket-chain conveyor system. Transverse troughs fitted with gates control the discharge into the various pockets. These pockets may have a capacity of from 5 to 20 tons each, and should be charged with different quantities so as to deliver any desired quantity to the engine. At medium-sized coaling stations, the coal may be dumped (or shoveled) into a hopper beneath the track and thence delivered to a vertical conveyor or a pair of dumping buckets for delivery into elevated pockets. The latter system is used in a number of cases by the Pennsylvania Lines; the buckets are of 2 or 3 tons capacity, automatically filled in pits supplied from the track hopper, and operated by steam or electric hoists. The storage capacity is from 150 to 350 tons, and the plants can handle from 75 to 100 tons of coal per hour.

The Pennsylvania Ry. has at Morrisville a 500-ton coal bunker of reinforced concrete, 170 ft. long, 14 ft. wide, and 8 and 16 ft. deep at the center and sides. The sloping bottom supplies 15 chutes on each side, having openings 3 ft. high and 5½ ft. wide. These supply the engines. Girders across the top carry the coal-car track. The Inman yard of the Southern Ry. at Atlanta has a coal trestle on the sloping side of a bank which forms the back of a coal pile; the trestle is 42 ft. high. Along the lower toe of the pile is a trestle for a locomotive crane hauling a grab bucket, the crane track being 23 ft. above base of coal pile. The coaling track is 830 ft. long, and the crane trestle 730 ft. long. The storage pile holds 20,000 tons. Three sets of coal pockets (each with 18 pockets of 5 tons capacity) are placed over two engine tracks (16 ft. c. to c.) and the spouts serve a third track. Under the two engine

tracks is a cinder pit 100 ft. long, which is also served by the crane. (See also Ash Pits.)

The Philadelphia & Reading Ry. has a plant of 1,000 tons storage capacity, and a capacity of handling 120 tons per hour. The coal is dumped into track hoppers and carried by a conveyor to a bin spanning seven tracks. There is a spout to each track, and four other tracks are served by a bridge on which small bottom-dump cars are run. The seven tracks have ash pits with chutes discharging into a conveyor which delivers the ashes to a 40-ton elevated bin. This conveyor can handle 20 tons per hour. The plant of the Terminal Ry. at St. Louis has an elevated storage bin of 1,000 tons capacity, filled by link-

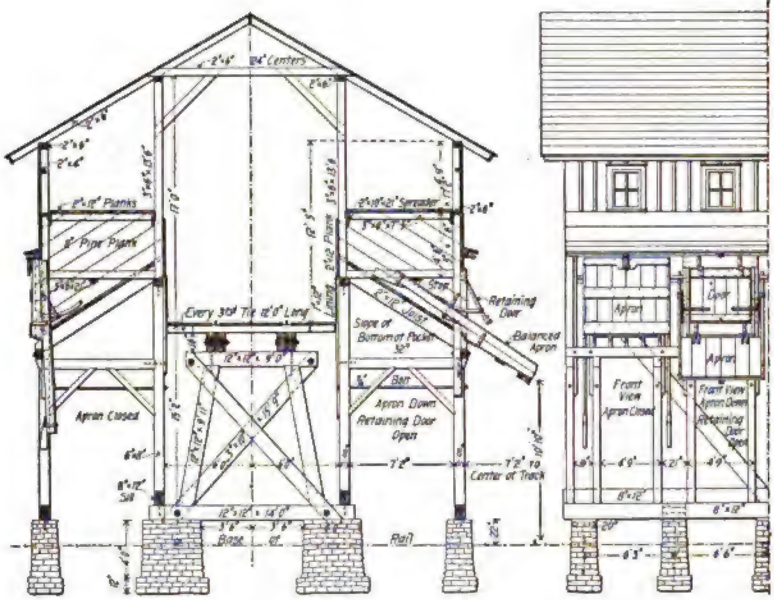


Fig. 128.—Coaling Station.

belt conveyors from the track hoppers, the conveyors having a capacity of 2,000 tons in 10 hours. The bin spans six tracks, and beneath it are 13 weighing hoppers of 15 tons capacity (one at the end serving a seventh track). About 200 engines are handled daily; seven can take coal, water and sand simultaneously, and 21 can have the fires cleaned simultaneously. In Fig. 128 is shown the construction of a coaling station fitted with chutes, the pockets being filled by shoveling from cars. The floor of the pocket is covered with No. 12 sheet steel and is at an angle of about 35° with the horizontal for bituminous coal, while anthracite will slide on a somewhat flatter angle. The door which retains the coal in the pocket is of oak, and is latched or unlatched by the movement of the apron. This apron, which may be of wood or iron, serves to direct the stream of coal into the middle of the tender, and when not in use swings up to a vertical position, covering the door of the chute. The apron is pulled down by the fireman by means of a chain, and is balanced by arms

which extend to the rear and carry an iron balance whose weight slightly exceeds that of the chute, so as to return it automatically to position when all the coal has run out. This avoids the use of chains and pulleys for counterweights. In the construction of a system of pockets, strength, durability and reliability must be carefully looked after. The rough handling and the dirt and dust are likely to cause any complicated mechanism to get out of order, but it is necessary to have the opening and closing of the chutes effected easily and quickly.

Ash Pits.

Where engine ash pans are to be cleaned, a common arrangement is to run the engine over a brick-lined pit, dump the ashes, and then shovel them up onto the ground and then into cars to be hauled away. The shoveling is unpleasant and expensive work, and should be reduced as much as possible. If the engine track is raised or the ash-car track is depressed, so that the floor of the pit will be somewhat higher than the sides of the ash cars, the ashes will merely have to be shoveled to the side instead of being lifted. One side of such a pit can be left open and the floor inclined, so that the ashes can be shoveled readily into the car. Iron chutes may be provided, down which the cinders will fall directly from the engine to the car, a water jet being used to wash down the heavier parts.

With narrow pits the rails may rest on stringers on the side walls. With wider pits the stringers may be carried on iron columns or brick piers. Two 15-in. I-beams under each rail, bolted together and connected by tie-rods, make a substantial support for the track, the span being about 15 to 20 ft. The ironwork, brick walls (of narrow pits) and piers, and wooden stringers, should be protected from contact with hot ashes by sheet-iron coverings. The pit in Fig. 129 is 80 ft. long. It has the outer rail carried on a 12×16-in. oak

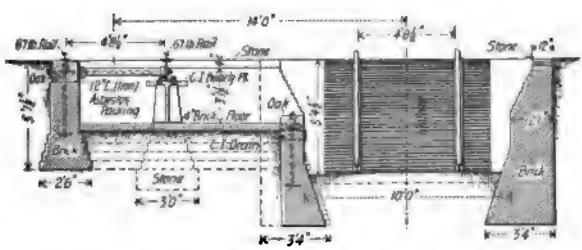


Fig. 129.—Ash Pit.

timber on the side wall, protected by a channel iron with asbestos packing; the inner rail is carried on a line of 12-in. I-beams supported by cast-iron pedestals 10 ft. apart. These beams are bolted through to the timbers by 1¼-in. rods, with 4½-in. sleeves. The floor is of firebrick and has an oak fender 8×13 ins. A pipe is laid on each side of the pit and provided with cocks to supply water for cooling the cinders and washing the pit. To enable engines on the main track to clean fires while taking water, the New York Central Ry. uses a shallow ash pit 30 ft. long, 11 ft. beyond the water column. A concrete bed 8 ft. wide is 16½ ins. thick at the middle and 12 ins. at the sides, which form benches for 12×12-in. longitudinal timbers connected by bolts

through the thicker part of the concrete These timbers carry the rails, and at each end is fitted a transverse timber. The inner faces of all these timbers are protected by angles 3½×6 ins., the narrower leg resting on the top.

Two parallel engine tracks may be served by a depressed ash pit between them. The Missouri, Kansas & Texas Ry. has at several points a pit 15 ft. deep, 11 ft. wide, with the upper part of the sides inclined to a top width of 23 ft. Over each inclined part is an engine track, and vertical steel doors from a pocket under each track. When ash cars are run into the pit, these doors are swung outward (being hinged at the top) so as to allow the ashes to slide down the inclined floors of the pockets and fall into the cars. If steel cars are used, the doors may be kept open when the fires are being cleaned, so that the ashes will go directly into the cars. The Chicago & Western Indiana Ry. has a somewhat similar arrangement but with two engine tracks (16 ft. c. to c.); each is over the sloping side of an ash pit 250 ft. long, 10 ft. deep below the rails and 12½ ft. wide. On the outer side of each pit is a track for a locomotive crane with a grab bucket for removing the ashes and loading them into cars. The same cranes handle coal from cars to the engine tenders. One of them also handles coal from a parallel storage pit of the same form and dimensions as the ash pits, and having a capacity of 1,250 tons. The coal-car track (16 ft. above the bottom) is over the inclined side of the pit. In another system the ashes are discharged into steel cars in a pit directly under the engine; these are run out of the side of the pit and up a 45° incline having an automatic device for dumping the ashes into a railway car under the inclined track. Each car is attached to a cable leading over a pulley to an air cylinder. There are two of these at the Milwaukee yards of the Chicago, Milwaukee & St. Paul Ry., serving 200 locomotives per day. The Pittsburg & Lake Erie Ry. has at McKees Rocks, Pa., a four-track ash pit, 125×55 ft., with a concrete floor and brick pedestals carrying I-beam stringers for the rails. This is spanned by an inclined girder on which runs a trolley hoist. The ashes are discharged into steel buckets 5 ft. long, of 47 cu. ft. capacity, running on narrow gage tracks. These are wheeled to the hoisting plant, lifted out and run up to a 35-ton elevated bin. Where large numbers of engines are handled, ample ash-pit facilities are needed. so that engines have not to wait for cleaning. At such large terminals some arrangement of mechanical handling is generally necessary. At some terminals the engines taking coal and water can at the same time drop their ashes into cars, buckets or conveyors.

Turntables.

A turntable for turning engines revolves in a circular pit from which radiate several tracks. The tables are from 60 to 90 ft. long, built for engines and tender loads of from 100 to 200 tons. They should be long enough and strong enough to take the largest and heaviest engines, should be well braced to resist racking, and should swing true and steady, it being borne in mind that they have heavy work to perform, and are often roughly used and indifferently cared for. The bearings, wheels and track should be carefully looked after, especially in roundhouse tables, as any failure of such a table may tie up all the engines. When turned by hand, two men bearing against levers at the ends ought to be able to operate them readily, but where many engines have to be turned, power operation is desirable on the score of economy in time and expense. A steam or gasoline engine or a pneumatic or electric motor may

be used, and may operate either turning gear or a small traction truck running on the circular rail of the pit and coupled to the end of the table. Motors of 10 to 15 HP. are generally used, and the compressed-air motor may be operated from the engine. The speed at the rim may be from 100 to 200 ft. per minute. The side wall, pedestal and floor of the pit may be of brick or concrete, the wall having a bench for the circular rail, which may be laid on wooden blocks or directly upon the masonry. The masonry should be of substantial construction. The pit may have a flat or dished bottom, a good arrangement in the latter case being to slope it from the side and center to a circular drain. The pit should be well drained and kept free from dirt, refuse and weeds. It is usually open, but sometimes covered by a circular deck attached to the table, though this latter plan is likely to result in a damp and dirty pit.

Turntables are of two general types: (1) Those which have a center bearing or pivot and a rim bearing of wheels running on a circular track at the circumference of the pit; (2) Those which swing entirely from the center. The Erie Ry. has a 65-ft. table of the first type, operated like a drawbridge. It has a drum 8 ft. 2 ins. diameter and resting on 32 cast-steel rollers. The ends have a rocking movement of ¾-in. A 15-HP. electric motor operates a train of gearing which ends in a pinion working in the fixed circular rack. The Strobel turntable is of the second type, having a horizontal faced ring which bears upon a live ring of conical rollers on the top of the pedestal, the rollers being held in their relative positions by a spider. The live ring is about 4 ft. diameter, and the table has a bearing upon it at four points, instead of at two points only, as in many tables. As an engine enters or leaves, the table rocks to take an end bearing on bolster plates, the use of end carrying wheels being optional. The Greenleaf turntable has conical rollers concentrated in a cap bearing (no spider being used), and the table is steadied by vertical guide rollers on vertical axes, these rollers bearing against the base of the pedestal. The table tips and locks in line and surface for the engine to run on or off, unlocks when the engine is completely on or off the table, and then balances to a horizontal plane. Continuous plate girders may be used, or cast-iron girders in halves fitted to the central box casting or frame which envelopes the pedestal. They may be of fish-belly or parallel-chord pattern. They are usually deck girders; through and half-through girders with shallow pits being used in a few cases. The turning and locking should be operated from a cabin on the turntable, and the lock may be connected to a target and lamp on the end so as to indicate to enginemen when it is safe to run on and off. At some passenger terminal stations in Germany there are turntables pivoted at the end; these are set in sidings and connect with lateral spurs to mail and express platforms. The pit is quadrant-shaped instead of circular.

Transfer Tables.

A transfer table runs on a straight track in a pit 15 to 24 ins. deep, at right angles to a number of parallel tracks, so as to transfer engines or cars from one track to another. It is generally used at shops (the locomotive and car shops often fronting on opposite sides of the pit), but is also sometimes used at rectangular enginehouses having parallel (instead of radial) tracks. The table is supported by several pairs of wheels running on rails spiked to ties, short blocks or longitudinals, the rails being usually 10 to 12 ft. apart. It

may be operated by steam or electricity. A 70-ft. transfer table of 70 tons capacity on the Union Pacific Ry. has nine sets of 36-in. wheels with flat chilled treads. Each pair of wheels is carried between the ends of a pair of I-beams forming the transverse girders of the table, the bearings being on top of the beams so as to keep the pit as shallow as possible. The nine wheels on one side are attached to a single shaft, made in sections, and this is driven by an electric motor of 15 to 25 HP., current being supplied by a trolley wire. The power is also used to operate a capstan for hauling cars on and off the table at a speed of 100 ft. per minute. The traveling speed is usually about 250 ft. per minute with heavy loads and 500 ft. with light loads. At the Louisville shops of the Louisville & Nashville Ry. there is a 100-ft. transfer table with a travel of 1,000 ft. and a speed of 1,000 ft. per minute.

Y-tracks.

Where many cars have to be turned, a Y-track may be more expeditious than a turntable. The Peoria & Pekin Union Ry., forming the terminal of a number of railways at Peoria, Ill., uses a Y-track for turning combination cars, sleeping cars, etc. A train is made up of 8 to 15 cars, taken out by a switch engine, and turned at the Y. This is about a mile from the car yard, and with a clear track the work is easily done in 30 minutes. The distance between switches on the straight line is 1,541 ft. One leg is of 441.7 ft. radius, 872 ft. long on the curve. The other is 1,445 ft. long, with curves of 716.8 ft. and 955.4 ft. at the stem and straight track respectively, connected by a tangent. The Peoria Terminal Ry. has at Pekin a Y-track for turning engines and freight trains, and another (with 90-ft. curves) for turning passenger cars.

Track Scales.

Track scales and wagon scales for weighing cars, wagons, cattle, etc., are required at many yards. They consist in each case of a platform supported on weighing beams connected to the usual form of graduated scale beams. The apparatus is mounted in a pit covered by the platform, although in a few cases the platform is suspended from scale beams housed in an overhead structure. The pit should have walls of concrete, brick or stone, with a concrete floor graded for drainage. Wagon scales are of 5 to 15 tons capacity with platforms 8 ft. wide and from 14 to 22 ft. long. These are set at points convenient to the driveway or team road. Track scales are usually from 45 to 60 ft. long when cars in motion have to be weighed. The capacity must be from 100 to 150 tons for the large cars and loads now operated. If the track is used for other purposes than the weighing of cars, a dead or through track is gantletted with the weighing track rails, the rails of the two tracks being 8 or 12 ins. apart. One of the dead rails is supported by the wall of the pit and the other by a wall or by stringers on pedestals within the pit, so that the dead track is independent of the weighing apparatus. This necessitates making the platform in two sections. Where cars run slowly, the switch connections between the scale track and the through or dead track may be one or two rail lengths from the scale, but for higher speeds the distance may be 150 ft. to insure steady running. All scales should be periodically tested with a test car, the actual weight of which is known only at the headquarters from which the car is sent out. This weight is varied from time to time in order to check any "jockeying" on the part of the scalemen. For a wagon scale, the scale

beams may be in a housing at the side of the platform, but where they are in general use this part of the apparatus should be in a cabin, as is usually the case with track scales. Occasionally two scales are used on parallel tracks about 22 ft. c. to c., with a cabin between. A single-beam scale indicates the total load, but a double beam enables the tare or light weight to be shown also, the light weight being taken from the figures stenciled on the car. In many cases a recording beam is used. Printed tickets are inserted in a receiver on the poise and when the proper weight is obtained a pressure of the latch causes this weight to be punched in a card or ticket. For track scales in busy yards, especially where strings of cars are weighed while in motion, an automatic recorder is frequently used, giving a printed record of the weight of each load as it passes over the scale. (See also the chapter on Yards.)

Bridge Tell-Tales or Ticklers.

Low overhead bridges are a constant source of danger to freight-train brakemen, whose duties call them on top of the cars to set the hand brakes, although the general use of power brakes has greatly diminished the necessity for this work. At such bridges, men on the cars must be warned to stoop or lie down, as there is sometimes so little headway that unless a man lies flat on the roof or steps down between the cars he is very liable to be killed or injured. A tell-tale or "tickler" is usually placed for this purpose about 100 to 200 ft. on each side of the bridge (or 50 to 100 ft. in yards). The ordinary form consists of a gallows frame with single or double post, having a row of ropes about 30 ins. long, hung from the cross-arm and reaching 3 to 6 ins. below the level of the lowest part of the bridge. When ropes get wet or frozen they will strike quite severe blows, and in this respect leather thongs or straps are better, but, unfortunately, brakemen have a propensity for cutting off the thongs for personal use. They also show their dexterity by catching the ropes or thongs and throwing them up as the train passes, so as to twist them around the cross-arm. To prevent this, as well as to prevent the wind from blowing the ropes over the arm, the ropes or thongs may be attached to a bar or screen suspended by links from the cross-arm, or each rope may be attached to the eye of a rod passing through the cross-arm. This last arrangement is shown in Fig. 130, which is for bridges and structures less than 19½ ft. clear above the top of the rail. The requisite dimensions are as follows:

	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.
Clear headway.......	15	6	16	0	16	6	17	0	17	6	18	0	18	6	19	0	19	6
Length of rope (A)....	4	1	3	7	3	1	2	7	2	3	2	3	2	0	2	0	2	0
Length of rod (B)....	3	5	2	11	2	8	2	5	2	2	1	11	1	11	1	11	1	11
Height from rail (C)...	23	0	22	6	22	3	1	10	21	9	21	6	21	6	21	6	21	6

The Delaware, Lackawanna & Western Ry. uses a post made of 5-, 4- and 3-in. gas pipe, 28½ ft. long, set 5 ft. 8 ins. in the ground. It is set in a hole filled in with concrete (1:6:12), and is anchored by two 3-ft. angles or old splice bars riveted to the bottom, which is swaged flat. The post is 6 ft. from the rail, and has a 10½-ft. arm and knee-brace of 2-in. pipe. An ash bar 2½×1½ ins., 6½ ft. long, is suspended 4 ins. below the arm. Into this are screwed 2-in. brass eyelets, 4 ins. c. to c., each carrying a strip of No. 12 brass spring wire about 4 ft. 10 ins. long, but reaching at least 6 ins. below the lowest point of the obstruction. This is used for any obstruction with less than 20 ft. clearance above the heads of the rails, and is set 150 to 200 ft. from it. The Cincinnati

Southern Ry. has suspended from the cross-arm (by three ½-in. eye-bolts) a wire screen, 8 ft.×2 ft. 8 ins., made of No. 10 wire, with 1-in. mesh and having a rim of ½-in. rod. From this are hung double-braided ½-in. cotton ropes, well knotted to the screen and having the ends bound to prevent raveling. The ropes are 3 ft. 8 ins. long, 6 ins. apart, with the ends 17 ft. 10 ins. above the ties. The post is 8×8 ins., with cross-arm 3×8 ins., and brace 3×6 ins. It is 8 ft. from center of track, or 9 ft. on curves; and the distance is the same when a double-post frame is used (in rocky ground). A different type of indicator consists of a light wooden rod (about 1½ ins.) projecting across the track at the proper height and so pivoted to the post that when struck it will easily swing aside, being returned to position by a suspended weight. If pivoted to a shaft set at about 45° and carried by a swivel it will swing upward

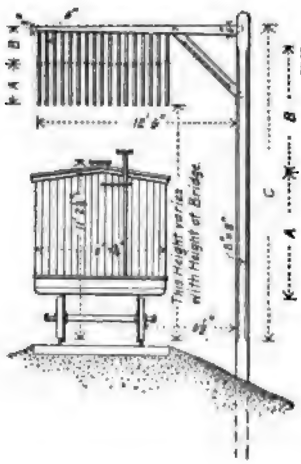


Fig. 130.—Bridge Tell-Tale.

and backward, and will be returned to position by gravity. These rods, however, may strike a severe blow unless nicely balanced, and are liable to become frozen fast. They are inferior to the other type, and are little used.

Where there are several tracks to be guarded, as on four-track lines and at yards, the ropes may be hung from a ¾-in. wire cable. Care must be taken to brace the posts well, and to provide means for taking up the slack of the cable, or it may sag so much as to strike a man and throw him from the train. For three or more tracks, the Delaware, Lackawanna & Western Ry. uses pipe posts as above described, 32 ft. long, sloped ¾ on 1 away from the track, and having wire guys at the back. Attached at 3 ft. from the top is a galvanized wire rope drawn taut and attached by loops or clips to a catenary cable which touches it at the middle and is attached to each post 1 ft. below the top. From the taut wire are suspended the cross-heads to which the brass ribbons are attached. On four-track sections the posts are 52 ft. 8½ ins. apart at the level of the rails.

Mail Cranes.

These are the frames to which are hung the bags to be snatched off by the "catcher" on the mail car of a passing train. The crane usually consists of a

post with two hinged horizontal arms, to which are attached the straps on the top and bottom of the mail bag. These arms extend towards the track, and when not in use lie vertically against the post, so as to be out of the way. A long swinging arm may be used to reach across an intervening sidetrack, but on four-track lines, where the inside tracks are for passenger trains, an iron crane is used by the New York Central Ry. It is set between the tracks, and has the upper part turned parallel with them when not in use. This is shown in Fig. 131, together with the gage for erecting it at its proper position

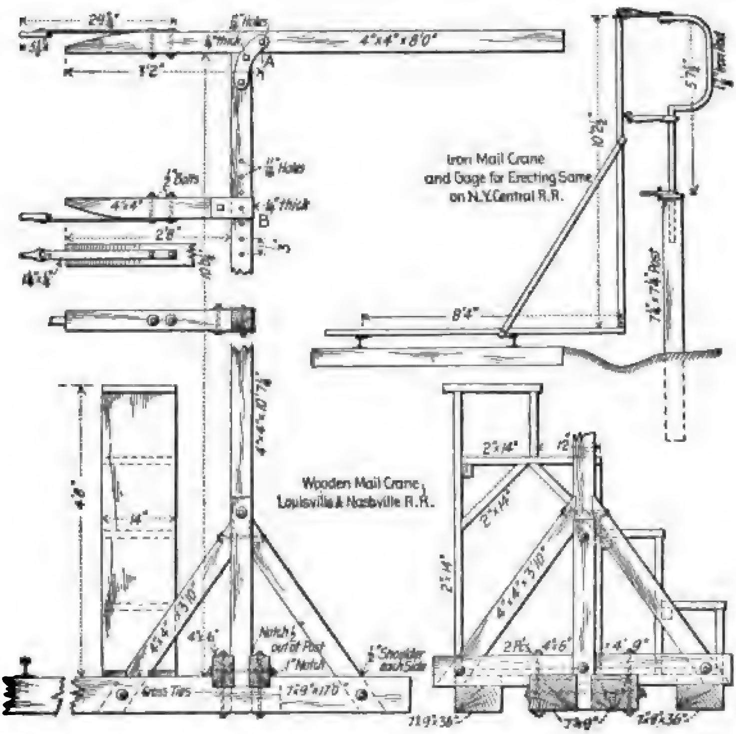


Fig. 131.—Mail Cranes.

in relation to the catcher on the mail car. When placed between passenger and freight tracks these are spread 15 ft. 10 ins. c. to c., and the center of the crane post is 7 ft. 5⅝ ins. from the center of the passenger track. The stand should be carried on the ends of two long ties, so that any alteration of level of the track by surfacing, heaving, etc., will not affect the relative position of the crane to the car and rail.

The wooden mail crane shown in Fig. 131 is very similar to that recommended by the Railway Mail Service Bureau of the Post Office Department. The arms are shown in position for the bag, but when it is taken off they swing to a vertical position, the upper one against the back and the lower one against the front of the post. Small rubber blocks prevent jarring when the arms fall. The iron tongues have no springs to hold the straps of the bags, a slight

groove in the irons and the tension on the straps due to the arms affording ample security. In the Post Office style of crane, the iron tongues are straight and flat, each with a light spring of curved steel to hold the strap. Sometimes the lower part of the post is enclosed in a box filled with stone, the steps forming a part of the box. Iron mail cranes of the same general form are also used. The face of the post is 6 ft. 6 ins. from the gage side of the rail, and the center line of the bag is 11½ ins. from that of the horizontal shaft (on the car) which carries the catcher arm.

The standard height of the crane is objectionable in bringing the upper arm in such position that enginemen are liable to be struck when leaning out of the cab window. In a few cases it has been raised, using a special attachment to suspend the top of the bag. Mail bags delivered from passing trains are usually thrown onto the ground or on the station platform; this is liable to cause damage to bags and mail, and injury to persons standing near. In England a loose rope net is placed beyond the end of the platform to receive the bag. Mechanical devices to deliver and receive the bags automatically are in experimental use to a limited extent.

Bumping Posts.

Bumpers or bumping posts are generally erected at the ends of tracks in yards and stations to prevent cars from running off. In some yards it is considered preferable to leave the ends open, except near buildings, as it is cheaper to rerail a car than to repair it after having struck the bumper heavily. In some cases it has even been found effective to replace the bumper by a flag, and to prescribe summary punishment for the first man who sends a car over the flag. In general, however, it is better to provide the posts and to rely on discipline to prevent the rough usage of cars. In some cases the stoppage of a car is of the utmost importance (as at stations, elevated lines, and near buildings or waterways or streets). There are many other cases where it is not advisable or necessary to erect an expensive bumper of such extreme stability as to wreck a car. A bed of sand or cinders to receive the wheels is an excellent auxiliary to a bumper. The Southern Pacific Ry. uses for permanent spurs at important stations a plank frame or three-sided box 10×10 ft., 2 ft. high, filled with sand, which covers the rails. At temporary spurs and spurs at unimportant stations it uses a truncated pyramid of earth, 3 ft. high, 15 ft. square at the base and 5 ft. on top. Some roads use a light bumper backed by planking and a bank of earth or cinders from 2 to 4 ft. high, with a slope of 1 on 2. Concrete blocks are sometimes used, and those of the Delaware, Lackawanna & Western Ry. are 9 ft. long (under the rail), 7 ft. wide, with the track rails embedded in the concrete. A granite striking block and reinforcing A-frame of old rails are also embedded in it.

A car may easily jump an ordinary low bumper consisting of a timber laid across the rails, but Fig. 132 shows a form of low bumper with two timbers which it would be almost impossible for a car to jump. The timbers are 33 to 36 ins. apart, and may be chained to the track. For minor sidetracks the New York Central Ry. uses a 12×12-in. timber laid across the rails and bolted against brackets which are bolted to the webs of the rails. High bumpers which will catch the car frame or buffer are generally preferable. The simplest form of high bumper consists of three heavy timbers: a longi-

tudinal sill, a vertical post, and an inclined back brace. These are all framed and strapped together, the sill being buried in the earth. A better form has two such frames, with a horizontal transverse timber or deadwood between them to take the blow of the car coupler or platform, and having anchor rods

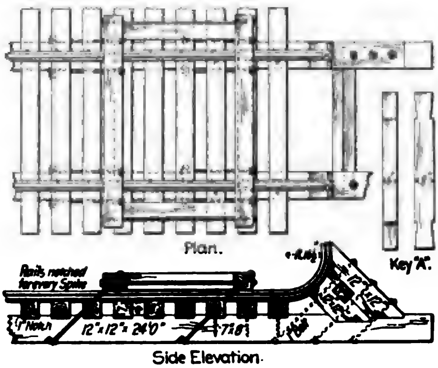


Fig. 132.—Low Bumping Post; Pennsylvania Lines.

to the front ends of the sills. The bumper shown in Fig. 133 is of this type, with chamfered edges to the timbers to give a good appearance in passenger stations. A bumper of the same type at the ends of tracks on a slight down-grade in a freight station (with a platform directly behind the bumper) has sills 14×14 ins. 50 ft. long, with five transverse 1-in. tie-rods and five transoms 6×14 ins. framed 1 in. into the sills. At 10 ft. from the rear end are two posts

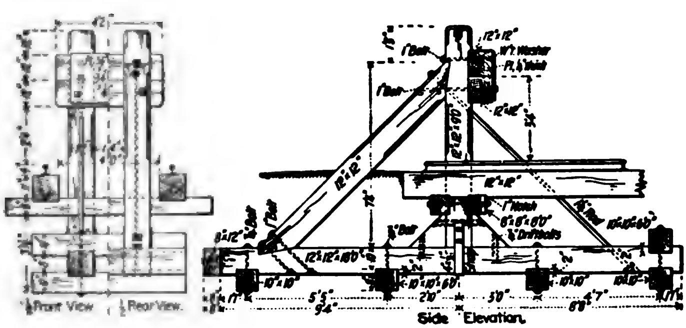


Fig. 133.—High Bumping Post; Louisville & Nashville Ry.

14×14 ins., 7 ft. 8 ins. high above the sills, with back braces 12×14 ins. and 2-in. anchor rods. The deadwood is 12×18 ins., and in front of this is a timber block faced with a ¾-in. iron plate 18×26 ins. Between these two timbers are six rubber blocks 6 ins. diameter and 5 ins. thick. The track ties are laid directly upon the sills. Instead of braces and anchor rods, long A-frames made of old rails, attached to the sills and passing over the ends of the deadwood may be used. Numerous special and patented forms of bumpers are in use. Where springs are employed to help absorb the shock, rubber is of little use,

having an insufficient range of compression and soon losing its elasticity and resilience when exposed to the air. Steel springs are also usually of insufficient capacity to take up severe shocks. In the Symons design, a steel A-frame is pivoted to castings on the track rails and is inclined backward at an angle of 45°; the apex carries a striking block and is supported by a curved post inclined forward and having its lower end nearly vertical. This end rests on a nest of coiled springs (or friction draft-gear) seated upon a casting on the track.

For terminal tracks in passenger stations, low bumpers are sometimes used, having double timbers with car springs set horizontally between them. High bumpers are more generally used. Some are of the type above described, but with two or three pairs of car springs placed between the deadwood and the striking timber. To prevent the springs from deflecting vertically, stirrup irons may be used, having the upper end bolted to the striking timber and the lower end embracing the rail or rail head. In front of the bumper may be a timber across the rails to catch the car wheels, or sand may be filled in over the rails for this purpose. Heavy plate-girder bumpers are sometimes built in passenger stations. The Ellis bumper, which is largely used for both passenger and freight tracks, has a heavy post set in the ground and carrying a rubber-cushioned striking plate. Two rails secured to the ends of the track rails by six-bolt splices are bent upward and inward to form an inclined V whose apex is bolted to a casting just behind the striking plate and resting on an oak block or post at the back of the main post. A friction-buffer (as used in the draft-gear of freight cars) has been suggested for use on bumpers. The Webb hydraulic bumper used on the London & Northwestern Ry. (England) is shown in Fig. 134. To the deadwood are attached two hydraulic cylinders,

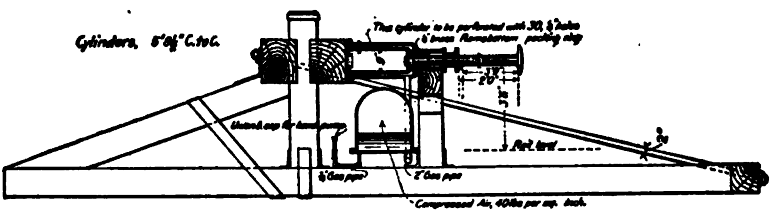


Fig. 134.—Hydraulic Buffer Stop; London & Northwestern Ry. (England).

the piston rods of which have mushroom heads to fit the spring buffers on the end sills of the cars. The cylinder is 9×24 ins., with the front end open and the sides perforated with 30 holes ½-in. diameter; it is enclosed in another cylinder, leaving an annular space of 2½ ins. An air chamber maintains a pressure of 40 to 45 lbs. in the cylinder, and this is retained for some months with one charge. The cylinder is filled with a mixture of petroleum, soap and water, insuring good lubrication. When a train strikes the buffers, the liquid is forced through the small holes and into the air chamber, the resistance increasing towards the end of the stroke as the number of holes for escape becomes less. A sand track has been used for this purpose in the terminal station at Dresden, Germany. (See Sand Track.) The number of the track may be indicated on a sign or target on the bumper, for the information of passengers and employees.

Terminals of elevated railways should be provided with specially strong bumpers, but those used are not always very substantial. They are generally similar to those used on steam railways, the posts being braced by timbers at the back and tied in front by rods to the structure. A movable stop-block to skid the front wheels might well be used in front of the bumper, the principle of the device being the gradual absorption of the energy of the train, and all the space that can be spared should be given up to it. Beyond the device, the track should incline sharply on an ascending grade, which rapidly grows steeper toward the end, thus absorbing the energy of the train. At the end should be a heavy timber bumper designed to take the shock of a collision and set perpendicular to the inclined track. For bumpers on docks and wharves, the sill should be the same depth as the track stringers and the track in front of the bumpers should be well anchored down, while a back brace may be put in between the bumping timber and one of the dock piles or a special pile. At ore piers and coal trestles the track sometimes ends with a grade of 25 to 30% for a length of from 15 to 30 ft.

Stop Blocks.

The use of stop blocks has been noted above, and a movable stop is shown in Fig. 135. The steel tongue (A) rests on the rail and is connected by a loop (B) at its rear end with a small grooved wheel (C) journaled in the sides of the strap. Between the wheel and the back of the tongue is a wrought-iron shoe (D) pivoted to the loop at (E); this rests on the rail and in a groove in the flat tread of the wheel. When a car wheel runs up on the tongue and strikes

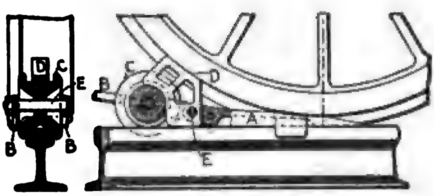


Fig. 135.—Rolling Stop Block.

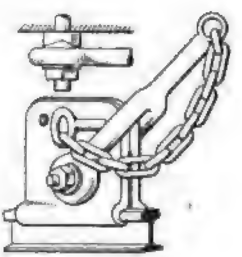


Fig. 136.—Portable Stop Block.

the shoe (D), this is pressed hard against the wheel and rail, stopping the revolution of the car wheel, while the force of the blow carries the stop block back along the rail until it comes gradually to rest, being held on the rail by the grooved wheel and the lugs on the tongue. A portable stop block for use in locking cars on yard or shop tracks is shown in Fig. 136, and may be fitted with a padlock. A fixed stop block used in engine houses on the Pennsylvania Ry. is a steel casting placed at the end of each rail. It is about 22 ins. long, exclusive of side bars which are bolted against the web of the rail. The upper surface is concave, with a radius of 10 ins., and the lowest part is 2½ ins. below the rail head, so that the wheel drops into it and is brought up against the end of the casting. The end projects only 3 ins. above the rail level, so as to clear the engine pilots.

Spare Rails.

It is the custom to place spare rails at the side of the track ready for use in case of emergency, and these are usually near the mile posts. They are generally carried on three stakes, 6×12 or 3×8 ins., 3 ft. to 4 ft. long, with the top cut like a step to form a seat for the rail base, or notched to hold the head and web of an inverted rail. When stepped, one is set with the step in the opposite direction to those of the others, so that the rail cannot be knocked off. They are set about 12 ft. apart, with the inner face 7 ft. from the rail and the top about 18 ins. above subgrade. If special attention is paid to neatness and finish, the ground may be dressed off level and covered with cinders and gravel for a length of about 33 ft. The spare rails are generally placed near the mile posts, but where they are more than a mile apart, it may be desirable to keep two or more rails at each place. In this case the tops of the stakes can be offset to give two seats 4 or 5 ins. wide, or iron posts with brackets may be used. The New York Central Ry. uses posts of old rails 7½ ft. long, set 4½ ft. in the ground, with plates ½×2½ ins. riveted across to form brackets carrying the spare rails; there are three posts 18 ft. apart. The Chicago, Rock Island & Pacific Ry. uses posts made from old 16-in. trestle stringers, set 30 ins. in the ground, with the narrow face 14 ft. from the center of track. The top is 21½ ins. above the ground, notched 3 ins. deep and 11 ins. wide, to receive two rails. The three posts are 18 ft. c. to c. The spare rails are placed at the middle and ends of every track section. The Southern Pacific Ry. has six rails on each main-line section and three on each branch-line section.

Hand-car Turnouts.

These are provided for convenience in taking hand cars off the track and storing them while the men are at work. The Southern Pacific Ry. places them ⅓-mile apart, every third turnout being at a mile post, though this arrangement is varied where necessary to avoid obstacles. The roadbed is extended to 11 ft. from the rail for a width of 9 ft. and covered with 3 ins. of gravel to the level of the bottom of the ties.

Buildings.

Many of the smaller buildings have to be looked after more or less by the track department. These include section tool houses; cabins or shanties for switchmen, flagmen and gatemen; signal towers; small stations and flag stations; and dwelling houses for foremen and sectionmen. Such buildings are usually of frame construction, and care should be taken that they are not allowed to get into a dilapidated and unsightly condition. The roofs may be of shingles, tin, tile, or roofing felt. Corrugated iron may be used also for the covering or paneling of small station buildings and gatemen's cabins, and for the covering of freight sheds. Brick and stone are often used for stations, and within the past few years there has been a marked development in the use of concrete for stations, section boarding houses, etc., giving permanent structures which are economical in cost of construction and maintenance. This may be in the form of monolithic concrete, or concrete building blocks. In the former case 6-in. hollow walls may be used, of concrete 1:3:5, with an exterior finish (placed in the form) of cement and sand, or a splash coat

put on afterwards. The monolithic concrete stations of the Atchison, Topeka & Santa Fé Ry. were described in Engineering News of Sept. 6, 1906; and small concrete block stations in July 13, 1905. The material and style of construction will depend largely upon local conditions, the climate, and the amount of attention paid to appearance. Buildings should be at least 7½ ft. from center of main track or 7 ft. from center of sidetrack.

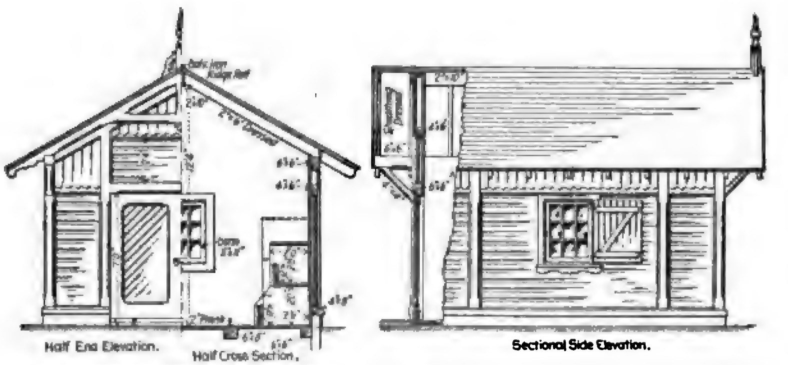
Painting.—For painting frame buildings of this class (of yellow pine) the following has been recommended as a priming coat: 100 lbs. of pure white lead in oil 4½ gallons of pure raw linseed oil, and 1 gallon of pure spirits of turpentine. This gives 8 gallons of paint ready for use. It should be allowed from three to five days for drying, or longer in damp weather, the second coat never being applied until the priming coat is thoroughly dry. The second coat may be composed as follows: 100 lbs. of pure white lead tinted to shade with not more than 12 lbs. of tinting material, 5 gallons of raw linseed oil, and 1 quart of good strong turpentine dryer. The third coat should consist of 5 gallons of pure kettle-boiled linseed oil to 100 lbs. of a paste composed of 60 lbs. of pure white lead, 30 lbs. of zinc white free from sulphides, and 10 to 12 lbs. of tinting material. Old and dry timber should be given a coat of pure linseed oil before being painted. For ironwork the following is recommended: Priming coat, 100 lbs. of pure red lead to 5 gallons of pure linseed oil; second and third coats (for black color), 20 gallons of pure kettle-boiled linseed oil to 100 lbs. of a paste composed of 65 lbs. of finely hydrated sulphate of lime, 30 lbs. of fine quality lampblack, and 5 lbs. of red lead. This makes 30 gallons of paint. If much painting is to be done, it is well to have it made from good raw materials purchased by the company; but for repairs and small jobs, ready-made paints of good quality may be used to advantage.

As to the color of the buildings, various shades and combinations are affected by different roads. A plain dark tuscan red is a serviceable color, and may be relieved by a darker amber brown on belt-rails, posts, etc. Two shades of green also make a good combination, but the dull yellow with dull red or brown trimmings (used by several roads) is very ugly. The tool house in Fig. 137 is painted in two shades of grayish brown, one being of a very light shade. The Chicago & Eastern Illinois Ry. uses a Vermont-stone color trimmed with olive-green, and black for the window sashes. One of the most attractive and cheerful styles is the colonial buff or yellow with white trimmings. A little light paint on moldings, etc., will lighten up almost any style of coloring. Paint having an admixture of sand may be used to finish the lower part of stations, where loungers are in the habit of whittling the boards. It has a very discouraging effect upon this destructive amusement.

The whitewashing of buildings, fences, cattle pens, etc., can be quickly, conveniently and economically done by compressed air. Several roads have cars fitted up with air-brake pumps and reservoirs, the pumps being driven by steam from a locomotive, and a pressure of 40 lbs. being maintained in the reservoirs. Tanks are also mounted on the car. The nozzle consists of an iron tube with a wide flattened end, and to each nozzle are attached two lines of ½-in. or ¾-in. hose, one from the air reservoir, and the other from the tank. The flow of air induces a stream of whitewash which is expelled in the form of a spray, the flow being regulated by a valve on the nozzle. Paint may also be used, being mixed somewhat thinner than when it is to be applied with a brush. This method of painting is not now much used, not being satisfactory. The advantages of

this method of working are the rapidity of the work, the saving in cost of brushes where rough or unplaned lumber has to be coated, and the general reduction in cost, while whitewash (or paint) thus applied readily finds its way to joints and narrow spaces almost inaccessible by a brush. On some large roads there is a regular traveling paint gang, which is carried from place to place on special cars fitted up with living accommodations and the necessary appliances.

Section Tool Houses.—Every track section must have a building to accommodate the hand cars, tools and supplies of the section gang. These build-



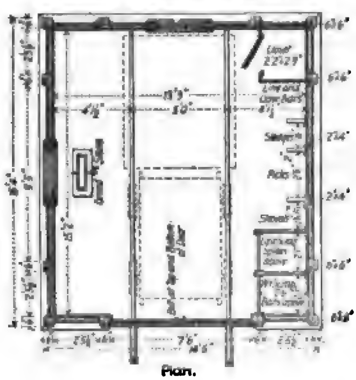


Fig. 137.—Section Tool House; Pennsylvania Lines.

ings vary in size and design, but should be large enough to hold the hand car, push car, tools, supplies, etc., and still leave room for the men to do such work as cutting shims, sharpening tools, sorting scrap, etc., in wet weather. The building is generally oblong in plan, and may be placed with its longer side towards the track, with the hand-car track laid through one end of that side, so as to leave the other end of the building unobstructed for the men to work in. It is well to partition off a separate room beyond or at one side of the hand-car track; this contains the work bench, vise, grindstone, lockers, stove, clothes hooks, etc. It should also have a shelf desk for the use of the foreman in writing up his reports, time books, requisitions, etc. In some cases miscellaneous supplies are stored in a loft or attic, accessible by stairs which may be hinged so as to lie against the ceiling.

Shelves, hooks and racks for tools should be fitted up to suit the equipment. There should also be boxes for small tools and supplies; and boxes, kegs or half-barrels for different kinds of scrap. Long-handled tools, bars, etc., may be stood on end, with the tops resting in horizontal hooks or in inclined notches in a shelf. Edge tools should be placed where they are not liable to injury. There should be a locker or cupboard for special or expensive tools. A sliding door, carried on an overhead rail, like a freight-car door, is generally prefera-

ble to double swing doors, as being more easily handled in stormy weather, and less likely to get out of order or to be damaged by being swung to and fro. There should be ample room for the hand car to stand between the house and the track without fouling trains.

The section tool house of the Pennsylvania Lines, Fig. 137, is 15 ft. 2 ins. × 13 ft. 3 ins. inside, with a track in the middle for the hand car and push car, which are shown by dotted lines. Double swing doors are used, and there is said to be no trouble in handling them. The Boston & Maine Ry. has a house of plainer design, 15½×24 ft., 10 ft. high from sill to cap, and covered with clapboards. The roof slopes ¾ on 1. There is a wooden floor on joists, and the clear height inside is 8 ft. to the joists of the attic floor, which is reached by a hinged ladder. The house is set parallel with the track, and not less than 8 ft. or more than 16 ft. from the nearest rail. The hand-car track is at one end. A long seat in the corner is formed by the boxes for bolts, etc. A sliding door is used for the car, and at one end is a small swing door. Where a double tool house is required it is 13×40 ft., with a room 12×14 ft. at each end, and a middle room 10×12 ft. for the men of both sections. A fixed stairway leads to the attic. The height is 12 ft. from sill to cap, with 8 ft. clear for the lower floor. A cobblestone pavement 4½ ft. wide is laid around the house, sloping to an 18-in. gutter. The tool house of the New York, New Haven & Hartford Ry. is 16×20 ft., with 8 ft. partitioned off for the use of the men and fitted with bench, locker, stove, etc. The double house is in duplicate, 32×20 ft. On the Georgia Central Ry. the tool house is 18×15 ft., with 5½ ft. at the rear partitioned off as a room. The New York Central Ry. section tool house for main lines is 20×14 ft., 11 ft. 6 ins. high at the sides. It is parallel with the track, 8 to 16 ft. distant, and has the car track laid in one of the 14-ft. sides. A 36-in. gravel or stone walk is laid around it. On branch lines the house is 18×12 ft., 11 and 16 ft. high at the sides and ridge. The windows are placed high up, and there are windows in the sliding door. All the houses are roofed and sheathed with shingles, stained green.

Section Houses.—In order to have the trackmen live on their sections it is often necessary to provide houses for them, the foremen very generally boarding the single men. They are usually frame structures, but in some cases of concrete blocks. In many cases they are very bare in appearance, but they may be made attractive with very little expenditure. To avoid monotony, three or four standard designs may be used. Fig. 138 shows a very plain house. Boarding houses should be well built, roomy and convenient. They should be made comfortable and kept neat, and these requirements are specially important for buildings far from a town, as good men will not stay in unpleasant quarters. Sometimes the house is furnished to the foreman, free of rent, and he is required to keep it in good condition and repair. On some roads a prize is awarded annually for the best kept section house and grounds. A simple and convenient plan is that of the Louisville & Nashville Ry., Fig. 139, and Fig. 140 shows the section-foreman's house of the same railway. A sketch plan of a dwelling house for sectionmen is shown in Fig. 141. The section-foremen's houses on the New York Central Ry. are 22×30 ft., with a one-story kitchen (9×8 ft.) behind the 22-ft. rear wall. At one corner is a porch with a door opening at the side into a living room 15×15½ ft.; adjacent to this are a dining room 13 ft. 8 ins.×8 ft. 8 ins., and a bedroom 13 ft. 8 ins.×12 ft. On the second floor are two bedrooms. The floors are double, with sheathing

paper between. The foundation posts and sills are of treated timber. The exterior is all shingled, and the interior finish is of pine $\frac{3}{4}\times3$ ins. On branch lines the kitchen takes the place of the bedroom on the first floor, and there are three bedrooms above. For gangs of Italian laborers a shanty $10\frac{1}{2}\times22$ ft. is used, 10 ft. high at the walls. The entrance is into a room $8\frac{1}{2}\times10$ ft., the other part being partitioned off to form a room 12 ft. long. On each side of this are four bunks (in two rows), the building accommodating eight men.

Telegraph and Signal Tower. A neat design of tower for telegraph operators, signalmen, etc., is that of the Chesapeake & Ohio Ry., shown in Fig. 142. It has two rooms, the lower one square and the upper one octagonal. The platform sills, joists and floor are of oak, while the timbers of the tower are of heart pine. The signal tower of the New York Central Ry. is 15×12 ft., with a one-story adjacent shed $13\times9\frac{1}{2}$ ft. for coal room, lamp room and toilet. The

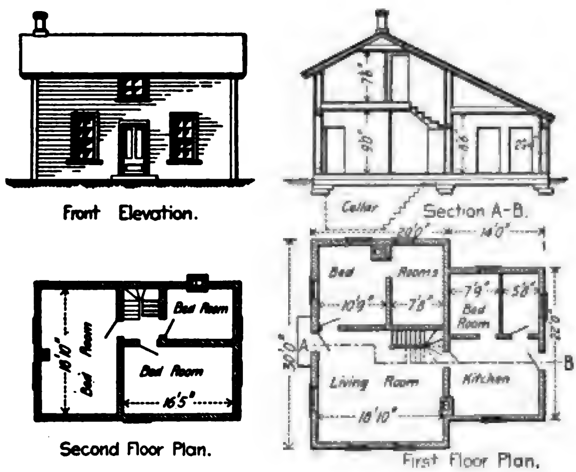
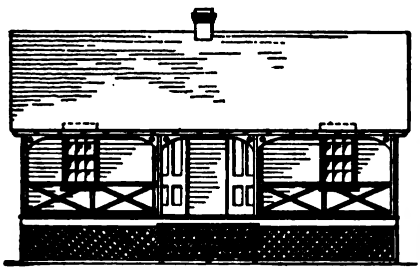


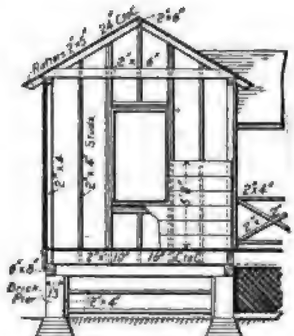
Fig. 138.—Section House; Canadian Pacific Ry.

operating room is reached by an outside stairway, with turns; the room is 8 ft. 4 ins. high, and its floor is 12 ft. above the rail. The roof has projecting eaves, and the entire building is sheathed with shingles.

Watchman's Cabin.—The cabins for watchmen, gatemen or switchmen may be square or octagonal. The latter gives the better view, and if two adjacent sides are extended to meet at right angles, the extra space will afford convenient room for a long bench and a berth. The cabin should not be less than 6 ft. square or diameter, $7\frac{1}{2}$ ft. high inside, and fitted with a chair, stove and locker for lamps, etc. There may be a shelter over the sidewalk where the man stands when operating the gates. On the New York Central Ry. the gateman has a two-story tower 9×9 ft., with a ladder to a trap in the floor of the operating room; this is $9\frac{1}{2}$ ft. high, with the floor 12 ft. above the rails. A surface cabin for switchmen and flagmen is hexagonal, with 4-ft. sides; a larger size has two opposite sides 6 ft. long. These are all 8 ft. 2 ins. high inside. An elevated cabin may be 6×6 ft. inside, with the floor 12 to 15 ft. above the rails. It may be carried on a single timber or built-up steel post. One common design has two posts 12×12 ins., set 6 ft. in the ground and provided with

sills and braces. On top of each is a cap 8×10 ins., 7 ft. long, with knee-braces, and upon these rests the cabin. For suburban crossings, where appearance of the cabins is to be considered, very neat and tasteful designs can be built at small expense. The comfort of the men should be carefully looked





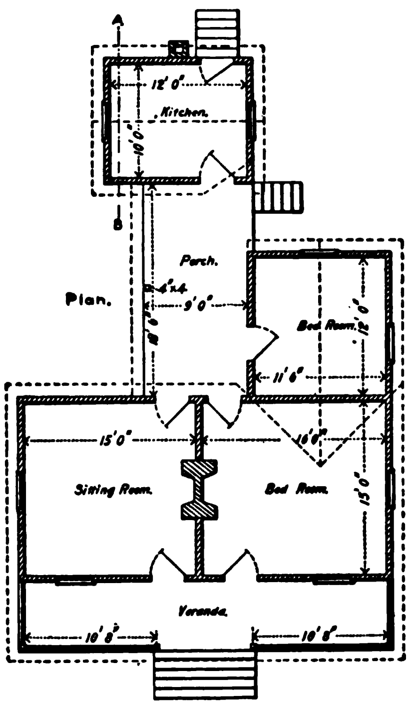


Fig. 139.—Section House; Louisville & Nashville Ry.

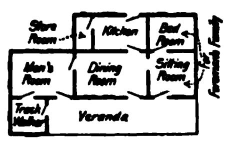


Fig. 141.—Plan for Section House.

to, an inner lining and ceiling or a layer of felt or tarred paper being used where the winters are severe. Similar cabins may be used for watchmen, yardmen, car inspectors, weighing machine-men, etc. In yards, and where the railway runs through the streets, it is sometimes necessary to place narrow cabins between the tracks or between the track and the roadway. These may be about 3 ft. 8 ins.×8 ft 3 ins., but should never be placed between tracks which are less than 15 ft. 6 ins. c. to c.

Station Platforms.

Railway-station platforms are usually level with or only a few inches above the level of the rail heads, except for elevated and some suburban railways, where the platforms are level with the car floors as in Fig. 93. The platform should in general be 3 to 6 ins. above the rails, and within easy reach of the lowest steps of the cars. The edge should be 24 or 33 ins. from the rail, or

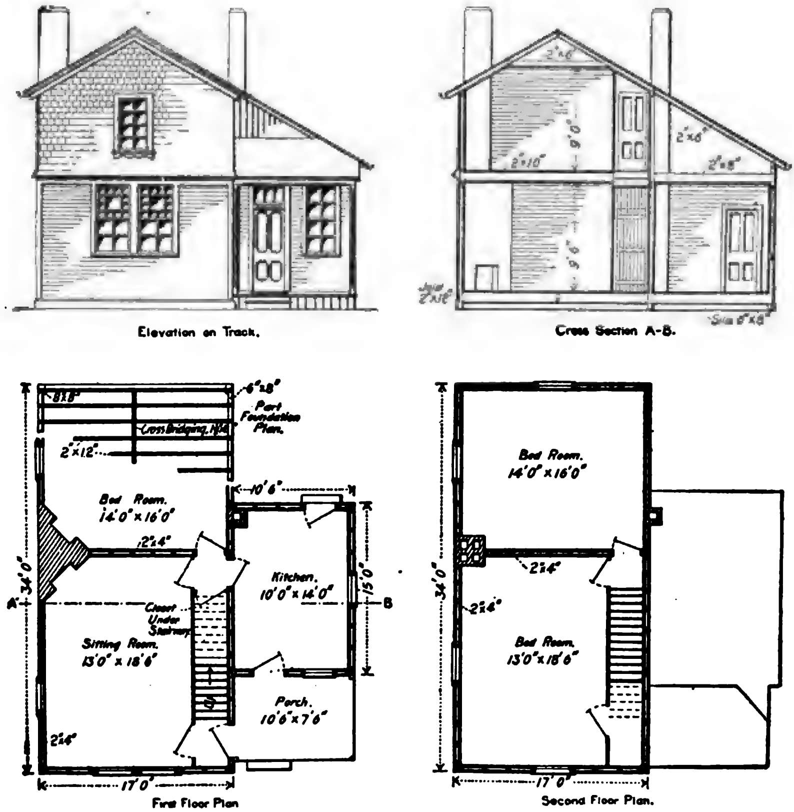


Fig. 140.—Section-Foreman's House; Louisville & Nashville Ry.

5 ft. 6 ins. from center of track. The main part of the platform should not be less than 10 ft. or 12 ft. wide, but at small stations the portions beyond the station building may be reduced to 6 ft. in width. Platforms between tracks are 12 to 15 ft. wide. The platform is generally one or two steps below the floor of the station building. It should incline slightly towards the track, while the ends should have an incline of 1 in 10 to the ground level. Where there is much passing across the tracks (though this should be avoided wherever possible), planking may be laid between the rails and between the tracks, being flush with the tops of the rails, and leaving the necessary flangeways. The New York Central Ry. places a rail laid on its side against the inner side of

each track rail to form the flangeway, with a 3×8-in. plank against this and another against the outside of the track rail. The planks are laid on fillers on the ties to bring them level with the rail heads. Between and outside of the planking is a filling of 3 ins. of 2-in. broken stone covered with 1 in. of $\frac{1}{4}$-in. to $\frac{1}{2}$-in. clean screenings; this surfacing is watered and rolled. This arrange-

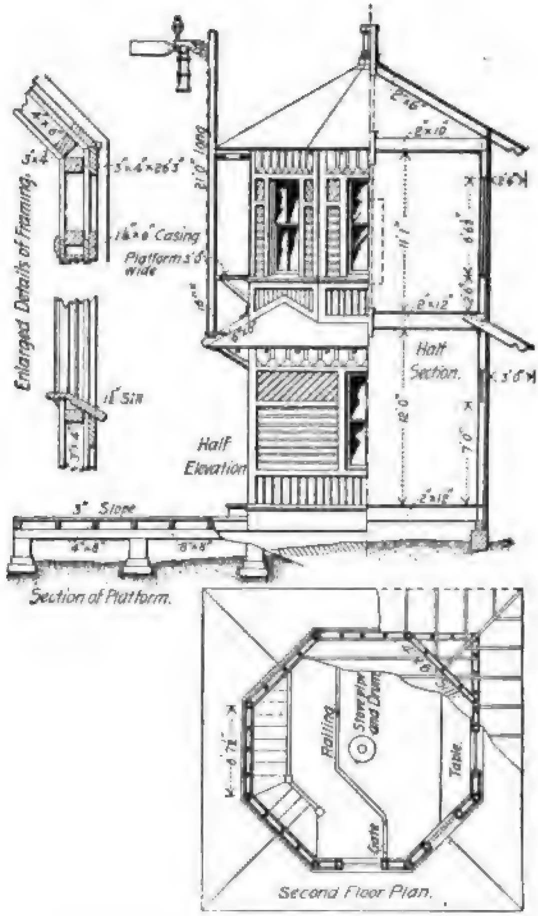


Fig 142.—Telegraph Tower; Chesapeake & Ohio Ry.

ment may be used for the full length of the platform, or for 10-ft. cross-walks. Freight platforms should be level with the floors of the cars, being about 3 ft. 8 ins. or 4 ft. above the rail, and having the edge at least 3½ ft. from the rail; this clearance limit varies on different roads. A platform about 3 ft. 3 ins. high should also be provided for handling freight to or from wagons and carts, an inclined approach being built in each case.

Brick, concrete and wood are the materials principally used, with asphalt occasionally in large terminal stations. Paving brick on 3 ins. of sand or 6 ins. of slag or gravel makes a good surface, but should have a curbing of stone or

concrete, as curb planks supported by stakes decay and become displaced. The Chicago, Milwaukee & St. Paul Ry. has adopted a curb of concrete slabs which are made at its yards and shipped as required. These are 24 ins. deep, 42 ins. long (41½ ins. on the bottom), 6 ins. and 4 ins. thick at bottom and top, with the outer corner rounded to 2 ins. radius. In one end is a slot 1¾ ins. deep and 2 ins. wide, extending 16¼ ins. from the bottom; the other end has a rib 1½×1¾ ins., 16 ins. high. Where greater depth is required, the slabs are 36×36 ins., and 7 ins. thick at the bottom. The concrete is a 1:2:5 mixture, made with ½-in. limestone, and there is no reinforcement. The stations on the Eastern Ry. of New Mexico have brick platforms 240 ft. long, 16 ft. wide at the building and 10 ft. at the ends. The pitch is ¼-in. to the foot; and the edge is level with the rail and 4½ ft. from center of track. At the rear and the end of the building (at the freight room) the platform is 3 ft. 8 ins. high, for convenience in loading and unloading wagons. A 4×10-in. timber wheel guard is bolted against the face of this. Inclines connect this with the lower portion, the incline to the front platform being against the end of the building. The retaining wall and curb are of monolithic concrete, 1:3:5. On top of a cinder filling is a 3-in. bed of sand, wetted and tamped; on this the paving bricks are laid (flat) with 1/16-in. to ⅛-in. joints swept full of sand. A concrete platform 12 ft. wide may have a pitch of ⅛-in. per foot, and may be a 3½-in. slab of 1:3:6 concrete, with a ½-in. finishing coat of cement and sand 2 to 1. Concrete cross-walks may connect such platforms. High platforms of reinforced concrete for the suburban stations of the New York Central Ry. have the top 4 ft. above the rail, and the edges 3½ ins. from the clearance line of the cars. The width varies, but there are two continuous 8-in. walls, with each side of the platform extending beyond the wall as a 30-in. cantilever. The floor slab or deck is 6 ins. thick, and the platforms are 350 ft. long.

Wood is commonly used for platforms, and where the surface is to be level with the rails, it may have pine planks, 3×6 or 2×4 ins., nailed to oak sills, 4×6 ins., laid at right angles to the rails and 24 to 30 ins. apart. The timber, however, is liable to be damp and to rot even if laid on sand, gravel or cinders, and under such conditions it will gradually develop holes which are likely to trip persons walking on the platform. It is much better to support the sills on small concrete or masonry piers, excavating the ground so as to leave an air space under the platform, as in Fig. 142. Oak posts or pile ends may be used instead of the piers. The sills slope 2 ins. towards the track. Upon the sills are joists or floor beams about 3×10 ins., 12 to 16 ins. c. to. c., laid parallel with the track and braced by bridging pieces. To these beams are spiked 2-in. floor planks. A layer of ashes or gravel should be placed under the platform, with its surface at least 5 ins. below the sills, so as to prevent the growth of weeds. For the ends of small platforms extending beyond the station buildings, an economical plan is to lay two lines of timbers 8×16 ins., connected at intervals of 10 ft. by transoms 6×12 ins., and ¾-in. tie-rods, between which is a filling of gravel or cinders. (See also Chapter 2.)

Platform Roofs.—In front of station buildings, a shed roof may be extended, but where the platform is covered, it has usually a roof supported on one or two rows of columns. In the "umbrella" type the sides slope down from the middle to gutters along the edges, but in the "butterfly" type they slope from the edges to a central gutter. This latter arrangement gives less drip and a

better protection to passengers. On the New York Central Ry. the edge of the "butterfly" roof is 14 ft. 10 ins. above base of rail and 4 ft. from center of track, extending over the car roof. Where the track is used by both passenger and freight trains the distances are 13 ft. and 6 ft., the latter in order to clear men riding in box cars. The "umbrella" roofs on the 15-ft. island platforms of the Dayton union station are 15 ft. wide, with the eaves and crest 13½ ft. and 17½ ft. above the head of the rail; 9-in. pipe columns are used. These platforms are from 700 to 1,000 ft. long and are connected by a cross-walk which is also covered.

Floors for Roundhouses and Shops.

For roundhouses, etc., brick is probably the best paving material, as it will stand heavy trucking, and is easily drained and kept clean. Hard-burned vitrified brick should be used, laid on edge on 2 ins. of sand with a concrete base, or upon a 6-in. to 12-in. rolled bed of cinders, slag or gravel. The floor should be tamped level, rolled and grouted with cement or hot tar. A wooden floor is very generally used, and the Altoona roundhouse of the Pennsylvania Ry. has 3-in. tongued-and-grooved yellow-pine planks on yellow-pine stringers 4×6 ins., embedded in stone ballast. A gravel or dirt floor is unsatisfactory, and causes dust, which is blown over the engines. In any case the floor should be kept in good repair. The rails may rest on longitudinal timbers 8×12 ins. or 12×12 ins., on the edges of the pits; or upon cross-blocks 6×8 ins. or 8×12 ins., covering the full width of the top of the pit wall (about 2 ft.). Concrete may be filled in between the blocks, and they may be covered with planking level with the rail head. This gives a good support for jacking or blocking. In some cases the rails are laid directly upon the concrete walls, or upon cast-iron plates on the walls. With longitudinal timbers, shims 2×10 ins. and the full width of the timber may be used, 8 ins. apart, to prevent wear or splitting of the timber. Stop blocks to prevent engines from overrunning the tracks have been noted above.

For tracks in shops, the rails may be laid on longitudinal timbers or cross-ties (with wooden or iron cross-ties under the former) embedded in or laid upon concrete; a tie-plate should be placed under the rail ends at each joint. They may also be laid directly upon the concrete, being held by clamps and nuts on 12-in. bolts bedded in the concrete, and having anchor plates on the lower heads. A groove or channel about 6 or 8 ins. wide should be left for each rail, to be filled in after with concrete, so that in renewing rails, etc., the concrete of the main floor will not be broken. A floor of this kind may be made as follows: 12 ins. of gravel, tamped and leveled; 3½ to 4½ ins. of concrete (1:2:4); 2 ins. of cement (5 sand to 1 cement), and a ½-in. finishing coat of equal parts of sand and Portland cement, or 1½ ins. of sand and cement 2 to 1. The shops of the Philadelphia & Reading Ry. have floors of bituminous concrete (cement concrete at pits) composed of 1 gallon of coke-oven composition to 1 cu. ft. of screened cinder, laid hot and well rammed. In this are embedded yellow-pine sleepers, 6×6 ins., 4 to 5 ft. apart, on which is an under floor of hemlock planks, 3×8 ins., with a wearing floor of maple boards, 1¼×4 ins., laid at right angles to the hemlock. Tracks are laid on pine ties 6×8 ins., 8½ ft. long, embedded in the concrete with their tops 5 ins. below the floor surface. The wooden floor is more comfortable for the men in winter.

A very general arrangement consists of 3-in. planking (or two courses of 2×8 ins.) on sleepers embedded in broken stone, gravel or cinders.

A tar-concrete floor may be made of a layer of clean, fine gravel and sand, well mixed with pitch and tar (1 part pitch to 2 tar); it should be from 1 to 2 ins. thick and laid on a 6-in. bed of gravel or of broken stone mixed with gravel to fill the voids. Plank floors laid directly upon cement concrete are subject to rapid decay, as the cement is hygroscopic and contains water in the pores, and is a good conductor of heat. Asphaltic concrete is a poor conductor of heat; it is antiseptic in its properties, and wood floors placed upon it have proved very durable, though the pungent smell of the tar lasts a long while, and may be objectionable in storehouses where certain goods are stored. The use of tar concrete is not advisable where heating pipes come near it, and in cement concrete fine crushed granite, in place of sand, will give a more durable and better-looking surface. The bottom planking should be well seasoned, and painted with some preservative, otherwise dry-rot may set in where any considerable area is covered by machines.

CHAPTER 13.—SIDINGS, YARDS AND TERMINALS.

Sidings.

Sidetracks may be considered as being divided into two classes: (1) Those used in train service; (2) Those used for storage and for switching movements at yards, stations and industries. The former are now very generally called "sidings," to distinguish them from tracks of the second class. The track of the latter is often of inferior construction, having light and worn rails, few and old ties, and a partial equipment of spikes and bolts. This may be permissible to a certain extent, but the track should be in good and safe condition for its service. A sidetrack in defective condition, with bad line and surface, is generally an indication of carelessness or neglect in the maintenance department. Freight sidetracks at small stations may be placed to suit local requirements, the freight-house track being (1) at the back of the combined passenger and freight building, or (2) between the main track and a freight house on the opposite side from the passenger station. The sidetrack may be slightly lower than the main track, so that cars will not foul the latter; it should be fitted with a derail for the same purpose. All turnouts should be well laid and ballasted, and kept up to the standard of the main track, while passing sidings should be maintained as part of the main track. Turnouts from main track should be protected by safety devices, as noted in Chapter 7, and their number should be as limited as possible. It is bad practice to multiply main-track switches by putting in spurs to industries, etc., with no other protection than an ordinary switchstand. The spurs can often be connected with a lead track or siding, the latter alone being directly connected to the main track.

Passing Sidings.

These are provided to enable opposing trains to pass on single-track roads, and also to relieve traffic by enabling freight or inferior trains to keep out of the way of faster or superior trains. Where they are long enough for the

inferior trains to continue running (instead of waiting for the superior trains to pass), they are known as relief tracks or relief sidings. On double-track roads the sidings may be placed between or outside of the main tracks. Lap sidings are so arranged that opposing trains can pass without either one having to stop. Passing and main tracks should be at least 13 ft. c. to c.

The turnouts of passing sidings and relief tracks should be equipped with interlocking switch and signal apparatus operated from a tower. Where manual block signals are used, this may be a block-signal tower. This is desirable not only on account of safety but to facilitate traffic with heavy trains. When switches are operated by hand, the train must stop to allow a brakeman to run ahead and open the switch, and then start again to pull into the siding. This means delay and expense, with liability to engine failures and the parting of couplers in starting a heavy train. Where a train takes an outlying side-track on a block section, and the block is thus clear and yet has a train on it, the towerman should be notified and give a following main-track train the "caution" signal. In such cases a bell circuit may connect the outlying side-track with the tower; in this way the conductor can notify the signalman or operator when his train is clear of the main track, and also when the superior train has passed the switch. There may also be an automatic indicator to notify the towerman when the main track is clear and when the train passes the switch. Still further protection may be provided by an electric switch lock controlled by the signalman or operator. When a middle relief track connects with the crossover connecting the two main tracks, the movement of trains from the relief track may be governed by the dwarf signal at the crossover switch. In order to allow of a second train being got clear of the main track when the relief track is occupied, the train may be switched onto the opposite main track, a call bell connected with the block-signal tower and interlocked with the dwarf signal being used to control the heading out of this train.

Arrangements for "lap" passing sidings are shown in Fig. 143. Plan No. 1 is a middle siding with the pulling-out switches at the tower. Westbound trains take the siding at (A) and pull out at (B); while eastbound trains take the siding at (D) and pull out at (E). The sidings are connected and have the end switches (C) and (F), so that in case of emergency the entire length of track can be used for trains in one direction. The telegraph tower is located at the center or "lap," the switches (B) and (E) being operated from the tower. This relieves the trainmen from responsibility for the switch when they have a clear signal to go on, and prevents them from pulling out onto the main track without the knowledge of the operator. Plan No. 2 is a middle siding in which trains pull in at the tower. Westbound trains enter at (B) and pull out at (C); while eastbound trains enter at (E) and pull out at (F). This plan is not used as much as the former. As the entering switches (B) and (E) are operated from the tower, trains do not have to stop before taking the siding. In order to control the outgoing movements and place the siding entirely under the control of the operator, an electric starting signal may be placed at the pulling-out switches (C) and (F). This is operated from the tower and interlocked with the switch, so that a train cannot pull out without the knowledge of the operator.

Plans Nos. (3) and (4) are outside lap sidings, the operation of which is similar to that of Nos. 2 and 1 respectively. These outside sidings are used on long, straight lines to avoid the necessity of putting the reversions in main track,

which the construction of a middle siding would require. The capacity of the siding for trains in one direction cannot, however, be temporarily increased, as with middle sidings, except by crossing over and interfering with through traffic in the other direction. The lap sidings may be placed at intervals of ten miles, additional sidings being built between them as the traffic may demand. By having sidings with a capacity for two or more trains, at short intervals, with switches operated from a tower so that trains need not stop, a high facility of train movement is obtained. When the traffic becomes too heavy for such a movement an additional main track or tracks will be required. The arrangement shown in Plan No. 5 is used where the sidings hold only one or two freight trains, and also where it is desired to maintain only one telegraph office. Where the third tracks are of such length as to lap over two block sections and get the use of these telegraph towers, the connections are made as shown in Plan No.

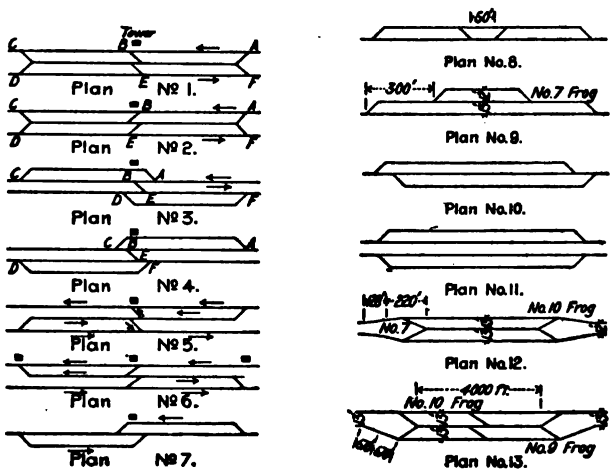


Fig. 143.—Plans of Passing Sidings.

6. A similar arrangement to Plans No. 3 and No. 4 can be applied to single track, as shown in Plan No. 7, and this greatly facilitates the handling of heavy traffic. With such an arrangement, two trains, headed in opposite directions and waiting upon the sidings, may proceed upon their respective ways immediately after the passage of the train on the main track, without waiting upon each other's movements. These sidings may be long enough to accommodate two or more freight trains, each of which pulls out as it gets the signal from the tower, the other following up to the tower. Thus trains in opposite directions do not interfere with one another, and no time is lost in waiting for train orders from a tower at a distance. The switches may be operated from the tower, the signalman being notified of the train orders. These sidings may be eventually extended to form a double track.

An ordinary passing siding is simply a piece of track parallel with the main track and connected with the latter at each end. Its length should be at least sufficient for the longest trains operated. If long enough for two trains, the middle should be marked by a sign, and it is well to have two crossovers, as in Plan No. 8. The New York Central Ry. arrangement of a single siding with

station siding or house track is shown in Plan No. 9. Double sidings for single and double main tracks are shown in Plans Nos. 10 and 11. In the relief-track arrangement on the New York Central Ry., Plan No. 12, one or both of the main tracks (12 ft. c. to c.) are swung out to a distance of 26 ft., with the relief tracks between. No. 10 frogs are used at the connections with the main track, and No. 7 at those with the relief track. The standard passing-track arrangement of the Union Pacific Ry. is shown in Plan No. 13; the siding is 4,000 ft. long, with middle crossovers, and the tracks are 13 ft. c. to c. No. 10 frogs are used at the main track and No. 9 at the relief-track connections. The main track on the station side is left straight, in order to give the operator or towerman a good view. The swing in the other main track is made by 10-min. curves 670 ft. long, so that trains can run at full speed.

Yards and Terminals.

The word "terminal" is applied to cover all the property and facilities at the end of the railway or division. The terminals may be subdivided into passenger and freight terminals, and further classified as line terminals, division terminals, rail and water terminals, branch or district terminals, etc. The word "yard" is applied to the system of tracks (independent of running tracks) which is provided at terminals and division points, stations, etc., for storing and switching cars in the work of making up and distributing trains. It is also applied indiscriminately to each group of tracks making up a general yard. Yard operations have an important bearing upon the cost and facility of transportation and the handling of freight traffic. The delays to cars in yards are among the most serious hindrances to the continuous movement of freight, and as through cars have to pass through a number of yards the cumulative delay may amount to days. At the smaller yards, inefficient construction or operation may lead to delays much greater than the time properly required for sorting cars, and at large cities there is additional delay where cars have to be transferred from one road to another. Within recent years great improvements have been made in yards and terminals with two special objects in view: (1) To increase the speed and facility of handling the cars in the necessary switching movements; (2) To increase the facility of handling freight in loading and unloading cars. These matters were discussed by the writer in a paper on "Railway Yards and Terminals," read before the Western Railway Club in November, 1900, and in an article in the Encyclopædia Americana (1907). (See also Engineering News, March 22, 1906, and April 4, 1907.)

Passenger Terminals.

As to passenger terminals and yards, very little can be said in the way of laying down general rules, the conditions and requirements varying so greatly in each case. Convenience of operation is usually of greater importance than economy of yard service, as the switching movements of passenger cars are comparatively limited. At terminal stations, the tracks are generally arranged in pairs, with platforms between, but in the Southern terminal station at Boston, the two tracks of each alternate pair are separated by a platform 8 ft. wide, used exclusively for baggage. These tracks are 17 ft. c. to c., while the passenger platforms are 14 ft. wide, the adjacent tracks being 23 ft. c. to c. The LaSalle St. station at Chicago has 11 tracks, spaced alternately 12 ft. and 24 ft. c. to c.

The Union station at St. Louis has 32 tracks in pairs, 800 ft. long, with approach curves of 12 and 13°. A subway system is provided to avoid trucking baggage on the platforms. The New York Central Ry. station at New York has 17-ft. platforms between the pairs of tracks, the platforms being 700 to 1,400 ft. long. The station of the New York Central Ry. at Albany has tracks in pairs between platforms 20 ft. wide and 20 ft. apart, with two rows of columns (for umbrella roofs) on each platform, 5 ft. from the edges. In the Pittsburg station of the Pennsylvania Ry., the pairs of stub tracks are 17 ft. between outer rails, and 20 ft. between the inner rails of adjacent pairs. The tracks of the Wabash Ry. terminal at Pittsburg are in pairs 12½ ft. c. to c. and 18 ft. c. to c., with 9-ft. platforms 12½ ins. above base of rails. Platforms between tracks should have a minimum width of 12 ft., and 15 to 20 ft. is better, especially if there are columns or if baggage is conveyed on the platforms. The main platform between a sidehouse station and the tracks (parallel with the latter) should be 20 to 30 ft. wide; while the transverse platform between the headhouse and end of tracks in a terminal station should be 30 to 75 ft. wide. At many large stations there must be both through and stub tracks, the latter for trains making these their terminal points. Stub tracks should be in pairs, and connected at their ends by a crossover or transfer table, so that the engine of an incoming train can be sent to the roundhouse, coaling station, etc., without the necessity of waiting for its train to be moved.

Ample connection should be made between the station or house tracks and the main tracks, with interconnections by slip switches, etc., so that there will be no liability of a station track being blocked. At the South station in Boston two intersecting double-track lines form an X in the middle of the yard, and cross all the approach tracks. At each intersection is a double slip switch, thus giving a great variety of combinations for connecting any of the 28 station tracks with any of the approach tracks. The special equipment for passenger yards will include express, baggage and mail-car tracks, car-cleaning tracks, inspection and repair tracks, car-storage tracks, engine tracks, turntables and transfer tables, coal and water supply for the engines, water for washing cars, attachments for charging gas tanks or electric storage batteries, water supply and ice for car tanks, etc. Passenger terminals were discussed in Engineering News, Jan. 12 and June 1, 1899.

The arrangement of tracks and track connections at stations of the smaller class is an important matter that is often overlooked. At stations having much local traffic, special tracks for the local trains should be developed from the main tracks. The tracks nearest the station should be for local trains and the outer ones for through trains. The points where the local tracks leave and rejoin the main tracks should be thoroughly protected by signals and interlocking plants, which may be controlled from the station. Where a through station on a main line forms also a terminal for branch or local traffic, the latter trains may be accommodated on stub tracks (generally parallel with the through tracks) at the end of the station. There should of course be the necessary connections between the through and stub tracks.

Trainsheds.—The trainshed at a large terminal may consist of a single arch or truss span, or a series of truss spans supported by intermediate rows of columns. The former system is not now in favor; it is costly, difficult to keep in repair, hard to light, and often damp and drafty. A modification of the multiple-span system is the low-roof trainshed of the Hoboken (New York)

terminal of the Delaware, Lackawanna & Western Ry. Rows of columns 43 ft. 4½ ins. c. to c. and 27 ft. apart longitudinally, 9 ft. 3 ins. high, carry plate girders with curved bottom chords; on these are purlins for the 2-in. concrete roof. There are skylights in the middle and at both sides of every span. Each span covers two tracks, and the headway is 16½ ft. above the rails at the middle of the span. Over the center of each track is a continuous opening 26 ins. wide, with concrete sides 25 ins. high, half above and half below the roof. This opening carries off the smoke from the engines, while the sides rising above the roof protect the platforms from driving rain. The girders are encased in concrete where they cross the openings. The platforms are 20 ft. wide, with the center and edges 7½ and 6 ins. above the rails. Some large stations have no trainsheds, but umbrella roofs over the platforms and over the cross-walks between the platforms. (See Station Platforms.)

Rapid-Transit Terminals and Loops.—On rapid-transit lines the headway between trains is largely dependent on the arrangement of the terminal tracks, for in practice trains cannot be run on a headway less than the time used by a train entering and leaving a terminal. It should not be necessary to stop a train to put it in proper order as to engine or cars, or put it on the proper track for the outgoing trip; nor should the arrangement permit an incoming engine to be blocked in, thus necessitating an exchange of engines. Quick service can best be made by arranging for the continuous forward movement of the trains, and avoiding the necessity of having the traffic in one direction cross that in the other direction. The "loop" system best fulfills the desired conditions, the loop being a circular track connecting the inbound and outbound tracks so that trains pass from one to the other by direct forward movement. At points where there is not room for a loop, space should be reserved for a

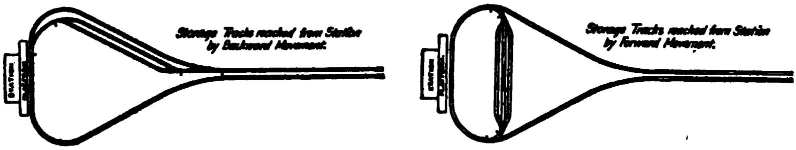


Fig. 144.—Loop Terminals for Rapid-Transit Railways.

number of parallel terminal tracks. If the room is so limited that even these cannot be accommodated, a trailing crossover should connect the two main tracks about an engine length from the end of the incoming track, so that an arriving engine can get out of the way without having to move against incoming trains or without having to wait for the train that it brought to be taken away. There should be another crossover a train length farther back to admit of the passage of trains from the incoming to the outgoing track. Double crossovers are sometimes used in such cases.

Loop terminals are now used in a number of cases. The New York station of the New York Central Ry. will have on the lower floor a terminal for suburban trains, with a number of parallel tracks (separated by platforms) all served by a double-track loop of 137 ft. radius. The South terminal station at Boston was designed with a double-track loop for suburban traffic, but in this case the platforms are on the loop itself. The Metropolitan Elevated Ry. of Chicago has loops at some of its terminals; the tracks diverge by easy curves (about 1,000 ft. radius) to tangents forming a Y. Along these are located the

station platforms, and beyond them the tracks are connected by a curve of 90 ft. radius. Within the loop may be inspection and repair tracks, opening from ladder tracks parallel with the Y. At the Wilson Ave. terminal of the Northwestern Elevated Ry. (Chicago) there are three platforms serving four parallel tracks. The trains pass round a double-track loop of 1,200 ft. radius and enter the station headed for the return trip. Tracks for the storage of engines and cars should be provided contiguous to the loop. These may be parallel to the flaring tangents of a kite-shaped loop, parallel with the main track (extended), or they may form connections across the loop. One of the plans in Fig. 144 requires no backward movements either in passing from the main track to the storage tracks or in returning to the main track.

Locomotive Terminal Facilities.

At terminal and division points, and where engines are changed, facilities must be provided for inspecting, cleaning, switching, turning and housing engines; and also for supplying them with coal, water, sand, etc. Several of these facilities have been described in Chapter 11. At the end of its trip, the engine is run upon a track for inspection, and then goes to the ash pit to have the fire cleaned; at this or other points it is supplied with coal, water and sand. It is then usually sent to the engine house, being reversed on the turntable before entering the house. Here the boiler is washed out if necessary, light repairs are made, and the engine is cleaned and put in condition for another trip. Where the engines merely lay over for a short time before making the return trip, they may be put on storage tracks in the open air; a series of radial tracks served by a turntable may make a convenient arrangement for this. The engine house is usually of circular or segmental form, with tracks radiating from a turntable. Rectangular houses with parallel tracks served by a transfer table are used in a few cases. Promptness is necessary in moving locomotives between the yard and the engine house, and the tracks should be so arranged that when an incoming locomotive has placed its train on the receiving track, it can proceed immediately to the engine house. Where engines have to be changed quickly, as at division terminals in the case of the engines of passenger trains, a track for the new engine should be placed near the changing point. The coaling station, ash pits, sand house and water supply should be near the engine house and easily accessible. Water columns should be located at the engine house, at points where switch engines work, at coal pockets (if distant from the engine house), and at the outgoing ends of the yard.

Freight Yards.

At division and terminal points provision must be made to receive incoming freight trains, to separate and classify the cars, according to contents or destination, and to put cars together to form outgoing trains. At division points through trains require only to have the engines and cabooses changed; and the cars, brakes, wheels, etc., inspected to insure that the trains are in safe and proper condition. General freight trains, however, are composed of cars of various commodities, and for various destinations. They have, therefore, to undergo a series of switching movements to separate and classify the cars. Some of the cars have to be set out for unloading at the division point; others have to be forwarded to local points on the next division, or sent through to the next division point; and still others have to be transferred to connecting

roads, or to be held for further orders. In the same way outgoing trains may be made up of through cars brought in over the previous division, local cars gathered up at points along that division, cars loaded at the division point, and cars received from connecting roads. Outbound local trains must be made up with cars in station order for distribution along the next division. At large terminals, cars may have to be distributed to freight houses, warehouses, team tracks, factories and industrial establishments, coal and ore docks or piers, grain elevators, local or district yards, etc. Cars loaded at these places must be collected at the main yard to be made up in through or local outbound trains, and empty cars must be distributed to points where loads await them. Upon the efficiency of handling cars in these complicated movements at freight yards will largely depend the efficiency and economy of the transportation service, as already noted. Items which enter into the cost of yard operation (exclusive of interest on capital invested and depreciation) include the following: the cost of yard engine repairs and supplies, wages of yard enginemen and firemen, switchmen, yardmasters, trackmen, signalmen, telegraph operators and way bill clerks; a percentage of general office expenses and of wages of train dispatchers; the cost of material used in track repairs, and the cost of labor and material used in the repairs of cars damaged in the yard. The investment in extra equipment made necessary by failure to handle cars promptly may also be a consideration.

On many railways the improvement of yards and yard service has been taken up very thoroughly. It may safely be said that on nearly every railway it would pay to make an extended and systematic investigation as to the design and operation of each important yard, and the means by which increased efficiency and economy can be secured; and then to follow this by a prompt and systematic undertaking of the improvements which are found to be desirable and practicable. One of the notable features of the railway improvement work of the past few years is the reconstruction and improvement of yards and terminals, and in fact such work is as important as the revision of grades and curves. The freight yards have been a defective part of the railway system as a whole, one reason for this being that the great expense and delay involved in switching and handling cars in yards has only been recognized by operating officers within recent years. Many yards of importance have developed gradually from smaller yards, and tracks have been lengthened, new switches and tracks put in, and alterations made from time to time as immediate requirements seemed to demand. Such a yard becomes eventually a mere patchwork of tracks and switches, the operation of which involves much unnecessary work and delay in handling the traffic, with heavy maintenance work. In large yards the traffic may not permit of entire reconstruction at one time, but a good and comprehensive design should be planned and gradually introduced.

Defects in yard design are frequently due to lack of co-operation between the constructing and operating officers. In some cases a yard is enlarged without the assistance of the engineer, the result being an awkward arrangement of curves and switches, which increases the difficulty of handling cars and increases the wear on wheels and rails. In other cases a yard may be planned without due enquiry into the local conditions and traffic requirements, with the result that the yard, while appearing very convenient on paper, is a source of much trouble to the operating department. Thus the switches may be badly located, or the track scales, repair tracks, or other special points may be incon-

veniently arranged or so located that they can only be reached by crossing or fouling other tracks which are in constant use. Railway engineers have generally given too little study to the operating side of railway service, and in consequence do not realize the importance of many smaller items and details in economizing work, or realize their relation to the general operating expenses of the railway. In the interests of efficient service it is imperative that the officers of the constructing and operating departments should consult together as to the best arrangement for any yard. Information should be sought from the yardmaster or other local officer as to any special or local service to be provided for, or any special difficulties resulting from the existing arrangement.

In enlarging a yard the idea often is to provide more tracks or trackage for cars, but a yard is intended for sorting and distributing cars, rather than for storing them. The quicker the car is passed through the yard from the time of its arrival off the road until it is delivered at its unloading point or sent out again to continue its journey, the greater will be the operating efficiency and economy of the yard service. This economy and efficiency will also extend through the whole freight service, for if the cars are handled promptly there will be less delay in providing empty cars as called for, and consequently the capacity of the equipment will be increased, thus avoiding the necessity of purchasing new cars. If a yard is too large, or its tracks too long, there is likely to be a lack of promptness in clearing it and getting the cars moving over the road. For this reason they are sometimes duplicated at important points; thus heavy freight (coal, etc.) may be handled at one yard, and general freight at an entirely independent yard in the same neighborhood. If a yard is too small, blockades will almost certainly occur, interfering with the movement of freight trains on the road, while the hurried and complicated switching in an overcrowded yard will tend to greatly increase the damage to rolling stock. In all yards there is more or less of a tendency to rough handling of cars, which can be kept in check only by strict enforcement of discipline, and a full enquiry as to the cause of and responsibility for each case of damage.

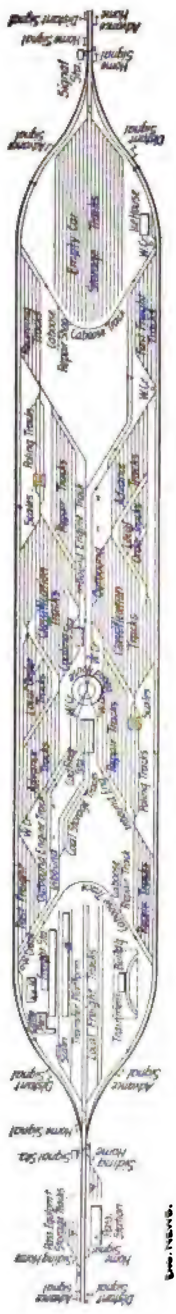
A main or general yard is subdivided into separate groups of tracks, each termed a yard, such as receiving yards, separating or distributing yards, classification yards and advance or departure yards; these are all interconnected and form the general yard. There will also be two general yards for traffic in opposite directions. The yards and tracks which make up the general yard must be so arranged in series that the cars will move steadily forward in the several switching movements, as all backward or reverse movements detract from the efficiency of operation. The location of the yard with reference to the main line is an important matter. It may be placed on one or both sides of the main tracks or between them. The first plan is objecttionable on account of the traffic in one direction crossing the other main track to get into the yard. The second is objectionable from the necessity of crossing the main tracks in passing from one yard to another. The third plan is not open to these objections, and as it usually provides for a sufficient separation of the main tracks to make room for the engine house and other facilities, the yard movements will not foul the main tracks from the time the incoming trains enter the yard until outgoing trains again leave the yard. Main tracks so located should, when practicable, be placed far enough from the yard tracks to admit of additional tracks being built in the space as required. At points where there are connections with the main track, these should be so arranged

that ordinary switching movements will not cause the main track to be fouled when the switch is set for main-track movements. This may be effected by connecting the main track and the lead or first yard track with a crossover, and extending the lead track beyond the crossover so as to form a "run-by." The connections with the main track should be as few as possible, and all equipped with interlocking plants to insure both safety and facility in handling the traffic.

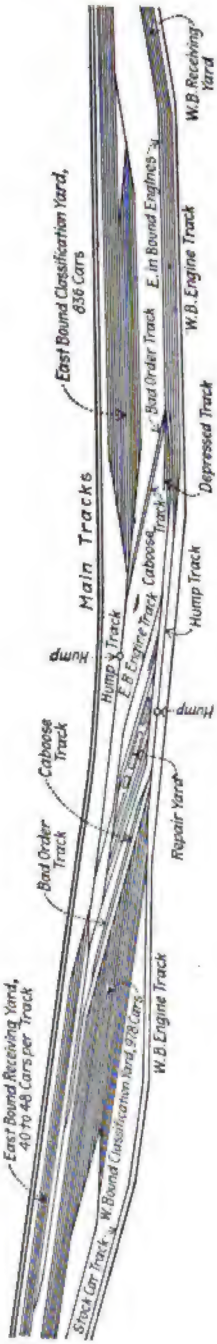
A "lead" track connects either end of the yard with the main track. The "body" tracks are the parallel tracks (in groups) upon which cars are switched or stored, and these are connected with or open from a diagonal "ladder" track. The ladder track is generally at an angle to the parallel tracks equal to the angle of the frogs. When it is necessary to divide a series of parallel tracks without breaking their continuity, a straight "ladder" track is run diagonally across them, the crossing of the tracks being effected by means of crossing frogs and the connection by slip switches, as in Fig. 54. Where there is a large number of tracks, as for a classification yard, it may be advisable to make the entering end wedge-shaped with two diverging ladder tracks, in order to concentrate the switches and also to lessen the wear of the frogs and switches by trains crossing them. One of the body tracks of each group is kept open or clear of cars, to allow of movements through the yard from one group to another. A "drill" track connects with the ladder track. It is generally parallel with but beyond the body tracks, and is for yard switching movements. Running tracks should be provided to enable the yard engines to pass from place to place in the general yard, and to enable both yard and road engines to go to and from the engine house, coaling and water stations, etc. A "house" track is laid alongside or inside a freight house, for cars loading or unloading. The body tracks should be 11½ to 13 ft. c. to c. The first yard track may be 15 or 20 ft. from the main track, to allow room for water columns, etc. Tracks for cars to be unloaded by teams may be in pairs 12 ft. c. to c., with driveways 25 to 30 ft. wide between the pairs. A ladder track should be 15 ft. from any parallel track. Repair tracks should hold not more than 15 cars each, and may be 18 ft. apart or alternately 16 ft. and 24 to 30 ft. c. to c., with a narrow gage track for material in each wider space. Part of these tracks should have air pipes for testing the brake apparatus.

In rating the car capacity of tracks, 40 ft. per car is usually allowed; or 50 ft. on repair tracks, to allow of work on the ends of the cars. The yard must include facilities for changing engines and cabooses, inspecting and repairing cars, supplying ice to the refrigerator cars, and water to the stock cars. Cattle pens, spur tracks to factories, docks, elevators, etc., may also be required at certain points. There should be ample crane equipment for handling heavy freight, so arranged as to serve both wagons and cars. Water pipes with hydrants 300 ft. apart may be provided in receiving yards for the use of car inspectors in cooling hot boxes. Air pipes may be provided at departure yards for testing the train brakes before the road engine is attached. Hydrants for fire protection should also be provided throughout the yard and in freight houses.

The discussion in detail of the design of individual yards is of little value since the conditions and requirements, the nature and extent of the traffic, and the size and shape of available land are so diverse. What may be a desirable and economical plan at one yard may be entirely inapplicable at another. A typical arrangement is shown in Fig. 145. An inbound train comes from the



(A) Plan of Typical Design for Freight Yard.



(B) Elkhart Yard; Lake Shore & Michigan Southern Ry.

Fig. 145.—Yard Plans.

main track to a receiving yard. In the separating yard the cars are arranged on separate tracks in regard to destination, commodity, etc. In the classification yard, cars are classified or grouped as required for making up trains, and in the departure or advance yard, the outbound trains wait for the road engines. Cars held for further orders go to the "hold" tracks or storage yard, and those needing repairs go to the repair or "cripple" track, whence they are shifted to the repair yard. Empty cars may be stored on separate tracks to keep them clear of yard movements. Cars with fast freight may also be set on separate tracks at the departure end of the yard; this facilitates making up and forwarding fast-freight trains ahead of the ordinary trains. The yard should be developed from one or two principal sidetracks so that the only switch in the main track will be that of the lead track. The receiving tracks should be long enough to take trains of maximum length, and the receiving yard should be of sufficient capacity to avoid blocking the main track by holding a second train until the first one is inspected, marked and distributed. The length of track should be approximately the same in all the groups. If the length is too great, it will necessitate switching the cars at high speed, making it dangerous for the men to jump on and off, and inducing a liability of injury to cars by colliding with each other. The aggregate length of the yard will also be excessive, causing considerable trouble in the movements of the switchmen and yardmen. The shortest classification track should be long enough to hold the cars of that classification for several hours' work, so that switching may be continued during a temporary blockade of the main line beyond the yard. The length need not generally be sufficient for a maximum train (except where these tracks serve also as departure tracks), but will depend upon local conditions and the number of classifications required. As a rule half a train length is sufficient, if an ample number of tracks is provided for the several classifications and for bad-order or "hold" cars. Where there are advance or departure tracks, the classification tracks may be somewhat shortened, but it must be borne in mind that the filling of one classification track blocks the classification of cars on all the others until the filled track is relieved. Spare tracks should, therefore, be provided near the classification tracks. The "hold" or storage tracks should be double-ended, or else there is a tendency to neglect the cars at the dead end. They should also be so connected with the classification tracks that in making up trains the cars can be taken from the classification or storage tracks, as required. The tracks for cabooses should be so located that the cabooses can be got out of the way quickly on the arrival of the trains, and can be readily delivered to outgoing trains. The outbound caboose track may have a 1½% grade to facilitate running the cars to trains in the departure yard. When there is room, a loop caboose track from the receiving tracks to the advance or departure tracks may be a convenient arrangement. When certain trains are run regularly by one set of crews, and others by another set, it will facilitate matters to keep the two sets of cabooses separate by providing two caboose tracks.

In team yards, where cars are unloaded by wagons, the tracks may be alternately 12½ ft. and 40 to 50 ft. c. to c., with driveways for teams in the wider spaces. The tracks may be parallel with the main track, or may turn off at an angle, according to the site. In some they are at an angle of about 45° with the ladder track, and have turnout curves of 20° or even 30°. For convenience in shifting cars, the tracks should hold not more than 20 cars each. The yard should have wagon scales, and a track scale should be located near

it. There should also be cranes for handling heavy articles; this may be some form of jib crane, or a bridge crane having a hoisting trolley which travels on a bridge spanning two tracks and half the driveway. The driveways should be paved with brick or stone where the team traffic is heavy; and should in any case be well paved with macadam or gravel to prevent mud and to enable the wagons to be hauled easily. The surface is generally about 1 ft. above the rails. The New York Central Ry. paves the approaches with stone on 2 ins. of sand and a base of 3 ins. of cinders or 6 ins. of concrete. The driveways between the tracks are macadamized; the base is 3 ins. of cinders or 8 ins. of slag or telford stone, covered with 3 ins. of 2½-in. stone and 1 in. of stone or slag screenings. This is crowned 2 ins. in 10 ft., and has paved gutters.

Yard Tracks.—One defect resulting from the general failure to recognize the important relation of yard service to the general operation of a railway is the poor quality of the yard tracks. Not only are the tracks very often of light and poor construction, but their maintenance is more or less neglected. Low joints, missing bolts, loose spikes, worn ties, poor ballast, and switches and frogs in bad repair, are common conditions in the average yard. The section-men in charge of the yard, finding it impossible to keep all these tracks in proper condition under the traffic which they sustain, naturally become more or less careless and discouraged. The switching engines (especially in smaller yards) are sometimes in corresponding condition, with tires worn hollow to an extent which is most destructive to the track. The heavy engines now being used at important yards call for heavy and substantial track to insure economy in operation and maintenance of the yard service.

The use of good rails in yards has been assumed to be unnecessary and uneconomical in view of the severity of the service and wear, and this is one reason for dilapidated yard tracks. But good heavy rails will reduce the wear of both tires and rails in yards as well as on the open road, and the expenses of maintenance of track and equipment will be correspondingly reduced. The cars will also run better. The New York Central Ry. introduced 100-lb. rails in the passenger yards of its New York terminal station, and obtained a decided economy in track work, in conjunction with other advantages. The tracks carried the heavy traffic between the station tracks and the four-track main-line approach, and were equipped with split switches, slip switches, turnout frogs and crossing frogs, all of the 100-lb. rails. The levermen in the interlocking tower at first claimed that it would be hard work to throw the heavy switch rails. As a matter of fact, these switches were found to work more easily than those with lighter rails, as the latter become bent vertically, causing them to bind on the slide plates, whereas the former were stiff enough to hold their shape. Concrete ties appear to be particularly adapted to yards, where renewals are difficult and costly, and apt to be neglected. An ample supply of ties, slide plates, etc., should be provided for yard switches, and the whole yard should be well ballasted, and well drained. It should be kept in good condition, one or more men being detailed to clear up scrap iron, paper, refuse, etc. It is often difficult to keep the yard neat and free from weeds, as the yard gangs usually have little time for this incidental work.

Split switches should be used, of a uniform pattern, and the frogs should be of one number, as far as possible. No. 7 and No. 9 frogs are largely used. The former (corresponding to 12° curves) should be used only where necessary, and not where road engines are operated. They cause more wear of the lead rails,

due to the increased curvature, but they bring the switches closer together. Where the yard property is rectangular, the sharper the angle between body and ladder tracks, the more economically will the ground be used, which is of importance for city yards. Sometimes No. 8 frogs are used, with the angle of a No. 7. Where practicable, No. 8 or No. 9 should be used, especially for the large engines used in modern yards. The diverging angle of the body track may be made as large as possible and the curve continued beyond the frog to make up the total central angle. In staking out tracks in a large yard, stakes of different colors for different classes of tracks may be used to avoid confusion, and the stakes of the mouth of switch and point of frog may be marked M.S. and P.F. respectively. (See also the chapter on Switch Work.) Complicated arrangements of switches, crossovers, etc., should be avoided. Slip switches, though valuable and often necessary, are expensive in first cost and maintenance. The switchstands should be of good make and kept in good order, and if the numbers of the tracks are painted on the switchstands or targets, the work of the yardmen will be much facilitated. Usually the yard switches are worked independently, but in a few large yards with heavy traffic all the switches of a ladder track, etc., are operated by levers concentrated in a tower. These need not be interlocked, and the entire interlocking of yard switching is impracticable on account of the complication. In some large yards the switches on the ladders of the classification tracks are worked by compressed air, on the Westinghouse electro-pneumatic system. All movements are controlled by push-buttons in a switchboard in front of the operator, and an indicator shows him when each car has cleared its switch.

Yard Switching.

The switching movements in separating or classifying the cars may be made in different ways: (1) Drilling. The train is pushed and pulled to and fro by a switch engine. Each car or "cut" (group) of cars is uncoupled in turn from the rear end; the train is pushed down the drill track and the uncoupled car runs by its momentum onto the desired track. This is not adapted for economical or efficient work in large yards. (2) Poling. The engine runs on a track parallel with that on which the train stands, and by means of a pole pushes each car (or cut), giving it sufficient impetus to run down the ladder track and through the switch of the body track for which it is intended. This avoids pulling and pushing the whole train to switch one car. The poling track should extend as close as possible to the ladder track, and may even be continued parallel with it, so that heavy cars or those which fail to reach their proper switches may readily be handled. A light grade (0.3 to 0.5%) on the ladder track will facilitate the car movements. The pole may be attached to the engine or to a special poling car. (3) Gravity. The cars are started on a descending grade which carries the cars to the classification ladder, along which they run by momentum to and along the desired tracks. This method has been largely adopted within recent years in this country, owing to the rapidity, facility and economy of working. If properly operated there will be less damage to cars and their contents than by other methods. It is specially adapted to large yards where large numbers of cars have to be handled. In a few places the natural slope of the ground provides the necessary grades, but as a rule a switching "hump" is built. The train is pushed up an incline to the summit of the hump, and as each car (or "cut") passes over it is uncoupled and acquires an impetus on the first or accelerating grade.

The grades in any yard vary with traffic and climatic conditions, and it may be necessary to use a steeper accelerating grade in winter. The summit of the hump should be a vertical curve of about 1,500 ft. radius. The ascending or approach grade is usually about 0.6 to 0.85%, increased to 1½% for 75 ft. at the summit to close the cars together. From the summit the grade is 2% to 4% (the latter where the grade must be short), followed by 0.75 to 1.50% along the ladder track, and 0.3 to 0.5% through the classification yard. Some examples of switching grades, with the recommendations of the Yards and Terminals Committee of the American Railway Engineering Association, are given in Table No. 16. The operation of freight yards is described in Engineering News, April 4 and June 13, 1907.

TABLE NO. 16.—GRADES FOR GRAVITY SWITCHING.

	From summit.	Ladder tracks.	Classification tracks.
Am. Ry. Eng. Assoc.; empty cars...	2.5% for 300 ft.	1.0%	0.5%
" " " " loaded cars...	2.0% for 300 ft.	0.7%	0.3%
Pennsylvania Lines; empty........	3.5% for 100 ft., or	0.75 to 1.25 %	0.4%
" " loaded........	1.5 to 3% if longer	1.25 to 1.50 %	0.4%
N. Y. Central Ry.; DeWitt; loaded *	4% for 150 ft.	1.0% for 1200 ft.	0.25%
" " " " empty †.	2.5% for 150 ft.	1.0% for 1200 ft.	Level
L. S. & M. S. Ry.; Elkhart.........	4.0%	2 and 1%	—

* Eastbound; mainly loaded. † Westbound; largely empty.

As each car starts from the summit, a brakeman mounts it and stops it at the proper point on the classification track. An engine or motor car running to and fro brings the men back to the summit. In making up outbound trains, all the movements are usually made by switch engines, although a second gravity movement may sometimes be introduced for this purpose.

The weighing of cars is a necessary and important item in yard work, both for commercial purposes and for making up trains on the tonnage-rating system, by which each engine is given a predetermined load to haul. The weighing is frequently done by track scales on the gravity track, the grade being so adjusted that cars will not pass too rapidly over the scales, which are 45 to 60 ft. long. Where a considerable proportion of the cars has to be weighed, the scale may be near the upper end of the accelerating grade. The grade over the scale should not exceed 2%, as a rule. When the scale is on a level track, a train may be pushed slowly over, stopping with each car on the scale or moving continuously, if the scale has automatic recording apparatus. (See Track Scales.)

The lighting of yards is rarely given much consideration, night work being done under adverse conditions by the aid of hand lamps. It must be admitted that the proper lighting of a yard is not an easy matter, owing to the interference of cars, whose black shadows alternating with lighted spaces, and moving from place to place, may be more dangerous than a uniform darkness to which a man's eyes become more or less accustomed. The matter is being given serious attention, and some few yards are now efficiently lighted. Electric lighting is the best for yard illumination, provided the lights are located with care. They cast a deep shadow, and unless they are located high over the tracks the shadows of cars and buildings near by will be troublesome. Lamps of 2,000 c.p. are recommended, spaced about 150 ft. along gravity or ladder tracks, and to give a clear view for about 300 ft. on classification or body tracks. They should be about 30 ft. above the rails. For gravity tracks the lights may be

placed on poles or on bridges, and fitted with reflectors to screen the light from the men descending the grade, and to direct the light forward along the tracks. Towers 100 to 150 ft. high, with clusters of lamps, may also be used for general yard lighting.

Freight Houses and Piers.

City freight houses are usually long and narrow, to accommodate a number of cars. Trucks can be run through one row of cars into the next, but if there are more than two rows of cars, there should be an 8-ft. trucking platform between the pairs. Widths of 25 and 40 ft. for the inbound and outbound freight houses, respectively, are very generally used. There may be a platform (with shed roof) on the track side of each house, but it is generally better to put the track close to the house. Shed roofs should be put on the driveway side to protect freight while being handled to and from wagons. For city freight terminals a problem of increasing importance is that of not only attaining efficiency and economy in the handling of cars and freight, but of attaining these ends on a minimum area of ground. In many cases it may be economical to abandon large city yards, selling the land or utilizing it for more remunerative purposes, and then to establish outlying yards on less valuable ground. Tracks would then lead to small local yards and central freight houses. To fully develop the area of these latter, the double-deck system may be introduced. Cars are successfully handled on grades of 6 to 25% at coaling stations and coal piers, and are also very generally handled on curves of 50 to 100 ft. radius in yards. Thus curves, inclines and elevators will enable tracks to be operated on at least two stories, with several floors above for warehouse or freight storage purposes. Such an arrangement is rarely used, but in a number of cases city freight houses are now combined with railway or commercial warehouses. These buildings have tracks on one floor, and the freight platforms are connected with the warehouse floors and the team platforms (on the street level) by elevators and freight-handling devices.

Freight piers at deep-water terminals are 50 to 150 ft. wide, and parallel piers should be 150 to 250 ft. apart. In freight houses on piers, with a dock on each side, from one to three tracks are required down the middle of the pier, the floor on each side being level with the floors of the cars. The tracks should have crossovers at intervals. Where warehouses are parallel with the wharf front, space can be economized by having spur tracks enter at the side, and run across the building. This will give more loading room than where the track is parallel with the building. This is especially the case where the tracks are in pairs, say 12 ft. c. to c., with trucking space of 15 to 20 ft. between pairs. The ends of tracks should be within reasonable distance of the wharf front to save as much trucking as possible. Conveyors or traveling platforms may be used to handle freight or trucks between vessels and piers. Freight-handling machinery is largely used in commercial warehouses, but not to any extent in railway freight houses, owing partly to the variety of sizes, shapes and weights of materials to be handled. There are important possibilities in this direction, however. Hydraulic and electric power is largely used at terminals in Europe, for operating cranes, capstans, car and freight elevators, turntables, etc.

Special siding and yard arrangements are required for coal and ore. At coal mines on the Southern Indiana Ry., the railway company sets empty cars on storage tracks having a grade of 1.25% to a ladder which feeds to the ladder of

four parallel loading tracks at the tipple. These are on a grade of 1.25% to 1.40%, and their lower ladder feeds to two or three tracks (0.75% grade) for loaded cars, ready to be taken away by the railway. The coal company's men handle the cars by gravity from the empty to the loaded car tracks. No. 8 frogs are used. This arrangement is shown in Fig. 146. Coal and ore storage and shipping piers are usually high enough to deliver the material by gravity from pockets beneath the tracks. Where the land is low, the trains or cars may be pushed up a grade by locomotives or hauled up a steep incline by a cable and dummy car to the floor of the pier; here an easy grade will carry the cars along the unloading tracks, and a steeper grade will return the empty cars to the storage yard below. The ascending grade may be at either end of the pier. Three arrangements are shown in Fig. 146. Machines for tilting and dumping the cars are used in some cases.

Car Transfers.—Where cars have to be transferred to barges or floats, transfer bridges are necessary to allow for varying stages of water and height of floats. The Pennsylvania Ry. terminal at Greenville, N. J., has three of these transfers. Each has a 41-ft. three-truss double-track wooden through bridge, with a rocking bolster at the inner end, while the outer end is suspended by heavy bars attached to 5-in. rods whose threaded ends pass through nuts on an overhead girder or gallows frame. The nuts can be revolved by bevel gearing driven from electric motors. Part of the weight is balanced by four 25-ton counterweights on cables attached to the trusses and passing over sheaves on the overhead structure, the counterweights being on either side. At the end of the bridge is hinged a trussed deck apron 32 ft. long, with its outer end suspended from

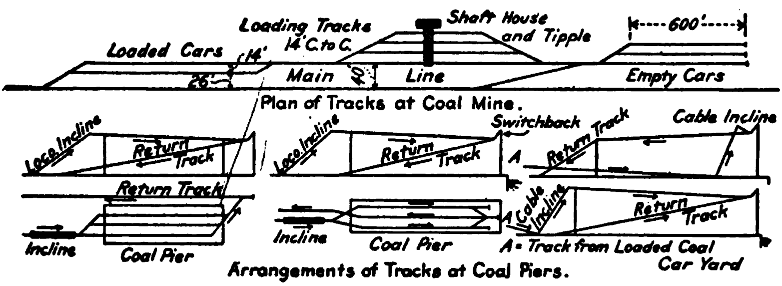


Fig. 146.—Arrangements of Tracks at Coal Mines and Coal Piers.

four pairs of cables which pass over fixed sheaves and sheaves on suspended counterweights. This apron is for adjusting the track level to that of the float. The range of adjustment is 11 ft. Electric hoists operate the mooring cables, and locking bolts secure the floats to the aprons. In other cases pontoons are placed beneath the outer ends of transfer bridges. The Missouri Pacific Ry. has a car-transfer ferry on the Mississippi River at Ivory, Ill., about 6 miles south of St. Louis. A double-track trestle with a grade of 4% extends about 900 ft. from high-water line, the lower end being about 10 ft. below low water. On the two tracks rides a single transfer car or cradle 180 ft. long, the top of which has a track with an ascending grade of 3% towards the river. Feather or tapered rails 12 ft. long connect with the rails of the trestle. The track stringers of the cradle are supported on crib bents 12 ft. apart, on stringers parallel with the trestle grade. These latter are carried by 20 pairs of 33-in.

wheels, with 20-in. and 12-in. wheels near the shallow end, and two pairs of sliding shoes where there is not room for the wheels. The outer 30 ft. of the cradle is formed by an apron of deck-plate girders, hinged on the second bent and supported by blocking on the end bent, beyond which it projects 12 ft. Each apron has three girders, the outer one being inclined away from the others to carry the outer rail of a switch to the outer track of a four-track barge. No. 6½ frogs are used on the aprons, with switches 62 ft. from the end. The tracks on the barge are 12 ft. c. to c., converging at the bow.

Sand Track.

A sand track for stopping runaway cars and trains has its rails covered with sand, which rapidly absorbs the momentum as the treads and flanges of the wheels run into it. This system is used instead of derails at two junction points on the Chicago loop elevated electric railway, the length of track covered being about 100 ft. This will receive and stop trains which may pass a home signal indicating "stop." The faces of the outside and inside guard timbers are 6 ins. from the gage side of the rail head, and a trough is formed by 2-in. planks wedged between the timbers and the bottom of the rail web, the joints being tarred. The sand just covers the rail head. The New Jersey & Hudson River Electric Ry. uses a sand track as a safety siding near the foot of a 7% grade. The track is 180 ft. long, with the switch normally set for the siding so as to catch runaway cars; a switch at the lower end allows of putting a car on the main track again without reversing. The 5-in. trough is formed by timbers 6×6 ins., and the sand is filled 2½ ins. over the rails.

In the Friedrichstadt gravity switching yard at Dresden, Germany, sand tracks were installed for stopping cars in ordinary switching work, few cars having hand brakes. They can take care of cars at a velocity of 14 miles per hour. The cars on the two gravity tracks of 1.8%, leading from the classification yards (1% grade) to the departure tracks, are controlled by portable stop blocks (Fig. 135). These are placed upon the rails by men stationed for the purpose. It was desired, however, to provide some means of stopping cars or trains which might get beyond control on the grade, so as to prevent damage to the cars or freight, and to prevent collision with trains in the yard at the foot of the grade. For this purpose a sand track was gantletted with the running track, as shown in Fig. 147. The latter track has main-line rails laid on thick

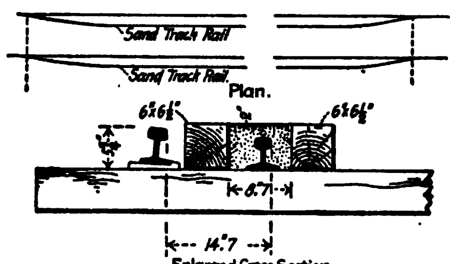


Fig. 147.—Sand Track for Stopping Runaway Cars.

tie-plates, while the former has lighter rails, giving a difference of about 1.05 ins. in height. Guard timbers are placed on each side of the lighter rail, and the space between them is filled with sand, covering the head of the rail by

about 2 ins. for a distance of about 1,150 ft. If a car gets away, a yardman throws the switch of the sand track and the car is promptly stopped. It is easily hauled back. On one occasion a freight train of 27 cars (with 55 axles), weighing 417 tons with engine and tender, got beyond control on the 1.8% grade. It was diverted onto the sand track while running at about 30 miles an hour, and ran for 328 ft. over a thin layer of sand and 738 ft. over a 2-in. layer. After the train was stopped, the sand was cleared away and the train then ran on through the lower switch to the running track. The ends of the tracks in the Dresden passenger station are covered with sand, as an auxiliary to the buffer stops or bumpers, but this involves a loss of track room, as trains must normally stop before reaching the sand track.

CHAPTER 14.—TRACK TOOLS AND SUPPLIES.

The tools used in track work are an important item in the proper maintenance of way, and they should be of first-class quality, as these need cost but little more than inferior tools, while they do better work and have greater durability. It is bad practice and false economy to purchase the cheapest tools obtainable, and to neglect to see that the tools are properly and carefully used. The use of steel instead of iron enables the weight to be reduced in many cases, without reducing the strength or efficiency of the tools. This increases the facility with which they can be handled. Tools with parts subject to wear should be bought under a guarantee that these parts are interchangeable.

Each track section should have a complete equipment of the necessary tools and supplies. Special tools, of which only a few are required, such as rail saws, rail benders, etc. (averaging one to 50 miles of track), should be kept at roadmasters' headquarters or other convenient points. Some roads also keep such tools as the following at these points, to be sent out to the section gangs for use as required: power rail saw, drill and bender; track wheelbarrows for ditching (6 to 12), scoop shovels (12), long-handled shovels (12), ditching spades (12), post-hole diggers (4), lawn mower, lights and torches. A few spare frogs and switch rails are usually kept at such points for emergency use, and the Southern Pacific Ry. requires each roadmaster's division to have at least 1,000 ft. of rail of fair quality for temporary tracks at washouts, etc. The distribution of spare rails along the line has already been mentioned. Two extra jacks on a division will usually be sufficient, but the New York, New Haven & Hartford Ry. at one time had a special gang to do all work requiring the use of jacks. On each division there will be a velocipede or inspection car for the roadmaster, and one for the engineer. There may also be the following for each division or a certain number of divisions: (1) A ditching car, with blades and mold boards for cleaning ditches and trimming ballast to the standard cross section; (2) A spreader car for leveling earth and ballast in widening banks, double tracking, etc.; (3) A steam-derrick car of 8 to 15 tons capacity for handling stone, lumber, etc., in emergency work or repairs; (4) A pile-driver car; (5) A flanging car; (6) A snow plow; (7) A wrecking train. At division headquarters there is often a repair shop for repairing tools, frogs, and switches; for making guard rails, and for sawing and drilling rails for switch repairs or other work.

There should be a good supply of tools maintained constantly in the store-

keeper's charge, so as to be ready to equip an increase of force in case of emergency, such as a flood, washout, snowstorm, landslide, wreck, etc. An accumulation of odds and ends of old articles and tools in the storeroom or the section tool house should be vigorously fought against. Extra gangs may be equipped on the requisition of the division roadmaster, who will be held responsible for the return of the tools to the storekeeper. Roadmasters and foremen should see that no unserviceable tools are kept on hand, but that when damaged or broken they are sent at once for repair, or requisitions made for new ones. Defective tools must be rejected, and the fact reported. The section foreman is held responsible for all the tools issued for the use of his gang, and it is a good plan to have the tools of each gang plainly stamped with the number of the section. A close check should be kept on all tools issued, and not more issued than are properly required by the section. Except for an increase of force, new tools should not be issued until those worn out or broken are returned, their disposal properly accounted for, or a satisfactory reason given for requiring the additional tools. A car should be sent over the division every month to pick up broken and surplus tools to be sent to the storekeeper, and the same car may collect the scrap from the section houses.

There should be some organized system for sending tools by train between the section and the shop or store. The ordinary tag on a bundle of tools is likely to be torn off or to have the address obliterated, and if this occurs on a bundle sent to the shop, the tools are either held or are sent out to some other gang, while the section to which they belong suffers from the delay. A good plan is to have brass disks or checks, like baggage checks, with the number of the section and name of station for that section stamped on one side, and the address of the shop on the other side. Two slots are cut at opposite edges for a leather strap, so that the strap can be slipped through to cover one side of the check, leaving the other side exposed to show the address to which the tools are to be sent. The checks for different divisions can be made of different shapes. The foreman should take a receipt in duplicate from the station agent for tools shipped; he retains one and sends the other to the shop. The carrying out of these check systems, and the enforcement of the rules above mentioned, will check carelessness, and result in a greater efficiency and economy as compared with the haphazard systems in force on some roads. Gages and levels should be periodically tested for accuracy. On some roads they are required to be sent in October to the division engineer to be compared with the standard in his office. They are then painted a distinctive color, so that roadmasters can see if the foremen have had these tools tested.

Each section should have a full equipment of good tools to supply every man, and some extra of such tools as have occasionally to be sent to the shop for dressing or repair. The number of these extra tools will depend upon the method of handling tool repairs and the frequency of the repairs required. The number of tools should be specified by the roadmaster, and the extra tools should not be put in use until the regular ones have to be repaired or renewed. For sections having stone ballast it is recommended that there should be two tamping picks at the repair shop (or on their way there) for every pick in service. There should be a shovel for each man and the foreman, and two extra shovels. Proper supplies and appliances, oil, lamps, etc., should also be furnished, and all appliances not in regular use should be kept ready for service. The section house, lockers, etc., should be kept locked when not in use.

The foreman should see that the tools are taken care of, and properly used. They must not be left on or between the rails, and not used for other purposes than those for which they were intended. He should also see that all tools and appliances are clear of the track before each train, and that the men do not wait until the last moment before quitting work in front of a train. Bars should not be thrown aside into the grass, where they are difficult to find, but should be stuck in the ground. Tools having bearings or cutting edges should not be thrown about on the ballast, where they are liable to damage by striking stones or other tools. The tools should always be taken to the section house at night, and not left out on the roadway. At the section house the tools should be placed on racks and shelves, or in tool boxes, and the sharp-edged tools kept carefully separated from the others. A little firm exercise of authority in disciplining the men as to the care and use of tools will result beneficially to the company.

Such tools as picks, bars, mauls, etc., are frequently made at the company's blacksmith shops, although they can usually be purchased ready-made almost as cheaply. The cost, however, varies with the skill of the men and the shop facilities, and whether the tools are made from new material or from the scrap heap of bridge rods, old tools, etc., always collected around a railway blacksmith shop. As a rule it is best to keep the scrap pile small and to purchase tools from reliable makers. The best design of tool should be aimed at, to secure the best service, and it is well to have as few different styles or makes of the same tool as possible. Claw bars and other heavy tools are often unnecessarily heavy, and of defective shape, while shovels are often too heavy and awkward to enable the men to do their best work with them. The desirability of adopting standard designs of track tools has been recognized by the roadmasters' associations, and some standard designs have been officially adopted. The actual adoption of these standards in service makes but slow progress, as individual roadmasters apparently still prefer their own familiar styles of tools, although they may have voted in favor of standard designs on general principles. Tamping machines have been tried experimentally, as well as machines for boring ties and putting in screw spikes.

The equipment given in Table No. 17 will be sufficient for ordinary section gangs. It varies on different roads and divisions, according to the ballast and other conditions of the track, the number of men, and the character and amount of the traffic. Ballast hammers and forks are not needed with gravel or soft ballast. Besides the tools, each section will usually have a supply of splice bars, bolts, nut locks, spikes, 5 lbs. of nails, 5 lbs. of fence staples, and a few extra pick or hammer handles. On a section where rocks are liable to fall, the equipment should include tools to facilitate their removal, such as rock drills or jumpers, stone wedges, blasting powder and fuse. When a special watchman is detailed to look after a dangerous rock cut, sliding bank, etc., he should be provided with a wheelbarrow, pick, shovel, and hammer; also two flags (or lamps) and torpedoes (or fusees). The following notes are explanatory of the lists in Table No. 17.

New York, New Haven & Hartford Ry.—This list is for a four-mile double-track section with stone ballast: 10 laborers in summer and 4 in winter. In addition to the material on the list there are 2 pick handles, 2 adze handles and 3 maul handles. If a tool is broken or worn out it must be returned to the storekeeper before another is furnished. This is found to be an economical

TABLE NO. 17.—TOOL EQUIPMENT FOR SECTION GANGS.

	Railways.				
	N. Y., N. H. & H.	L. & N.	Mich. Cen.	C. & N. W.	G. R. & I.
Miles: Single track		6	4	3	5½
Double track	4			6	
Ballast	St.	St.	St.&Gr.	Gr.	Gr.
Number of men	10	8	3	8	4
Spiking mauls	5	4	2	4	2
Hammers: Striking	2	1		1	1
Ballast		6			
Trackwalker's					
Nail	1		1		1
Sledges	2	2	1	1	1
Tamping bars	6	12	4	8	4
Lining bars		4	4	8	4
Chisel-point		1			2
Diamond-point	8				2
Pinch bars	1	2			1
Raising bars	1				
Claw bars	4	2	2	4	2
Spike pullers	1	1			1
Picks, clay	6	8	4	8	6
Tamping picks	12	8	4		4
Scoops				8	6
Shovels: Track	10	9	4	8	6
Snow	8		4		6
Long-handled	2				1
Ballast forks	6	6	4		
Axes	1	1	1	1	1
Adzes	4	1	2	4	4
Hatchets	2	1	1	1	1
Steel square	1				
Wrenches: Track	6	5	4	4	6
Trackwalker's		1			2
Monkey	1	2	1	2	1
Rail cutters	8				
Punch, square	1	1	1	1	1
Ratchet drill	1	1	1	1	1
Brace	1	1			1
Files	1	1			2
Chisels, rail	8	4	4	4	6
Hand saw	1	1	1	1	1
Cross-cut saw	1	1		1	1
Scythes and snaths	6	8	4	6	4
Bush hooks	1	2			2
Grub hoes		4			1

	Railways.				
	N. Y., N. H. & H.	L. & N.	Mich. Cen.	C. & N. W.	G. R. & I.
Rakes: Wood	4	2		2	1
Iron	1				
Hand car	1	1	1	1	1
Push car	1	1	1	1	1
Velocipede	1				
Track jack	1	6	1	2	1
Track gage	2	2	1	1	1
Center gage	1	1			1
Level board	1	1	1	1	1
Sighting boards	2				
Sighting bobs	2				
Spirit level		1	1	1	1
Tie square	1	1			1
Rail tongs	4	4		3	2
Rail bender	1		1		
Tape line, 50 ft.	1	1	1	1	1
Ditch line, 100 ft.	1	2		1	1
Wire stretcher	1			1	
Padlock and chain	1	2	2	2	2
Oil can	1	2	1	2	2
Oiler	1	1	1	1	1
Brooms	6	2	4	4	6
Grindstones	1	1	1	1	1
Scythestones	6	1	4	4	4
Wheelbarrows	1	8		1	
Water pail and dipper	1	1	1	1	1
Water kegs		1			1
Whitewash brushes		6		2	
Tool boxes	1	1			1
Flags: Red	3	4	2	2	2
Green	2	4		2	2
Yellow	2				
White		1	2		
Lanterns: Red	4	2	2	2	2
Green	2	2		2	2
White	4	2	2	2	2
Torpedoes	6	12	24	12	12
Shims		50	5 boxes		1,000
Spike-hole plugs	1,000	1,000	1 box		1,000
Track bolts	½ keg	2 kegs	2 kegs	1 keg	400
Nut locks	100	500	500	100	500
Spikes	1 keg	2 kegs	2 kegs	1 keg	400
Angle bars	6 pr.	12 pr.		20	10 pr.

plan. The tools listed include 10-lb. striking hammers, 16 to 20-lb. sledges, 6-ft. pinch bars, 7½-ft. raising bar, 15-in. monkey wrench, 16-in. files, and a 1-gal. oil can. There are six points for the drill. The list for a six-mile section of single track, with gravel and sand ballast, and 7 or 8 men, is practically the same, the principal exceptions being as follows: 4 spiking mauls, 12 tamping bars, 4 lining bars, 3 claw bars, 4 scoops, 15 snow shovels, 8 scythes and snaths, 2 bush hooks, 1 rake, 4 brooms, 8 scythestones, and 12 torpedoes.

Louisville & Nashville Ry.—This is for a stone-ballasted section with 6 miles of single track, and 8 laborers. In addition to the materials given in the list, the gang has the following supplies: 6 pick handles, 6 spike maul handles, 2 switch locks, two fillers for gage to widen curves (¼-in. and ½-in.), 2 ditching trays with aprons, 1 pair wire pliers, 6 stone crackers, 6 spalling hammers, 25 lbs. of 8-in. boat spikes. This road uses a mattock (with blade each side of handle) instead of the single-bladed grub hoe.

Michigan Central Ry.—This is for a section with 4 miles of single track, and 3 laborers to the gang. Both stone and gravel ballast.

Chicago & Northwestern Ry.—This is an average equipment for a section having 3 miles of single track and 3 of double track, all with gravel ballast, and with an average of 8 laborers to the gang.

Grand Rapids & Indiana Ry.—This is for a section with 5½ miles of single main track, and 4 laborers to the gang. Slag, gravel and sand ballast.

Description of Tools.

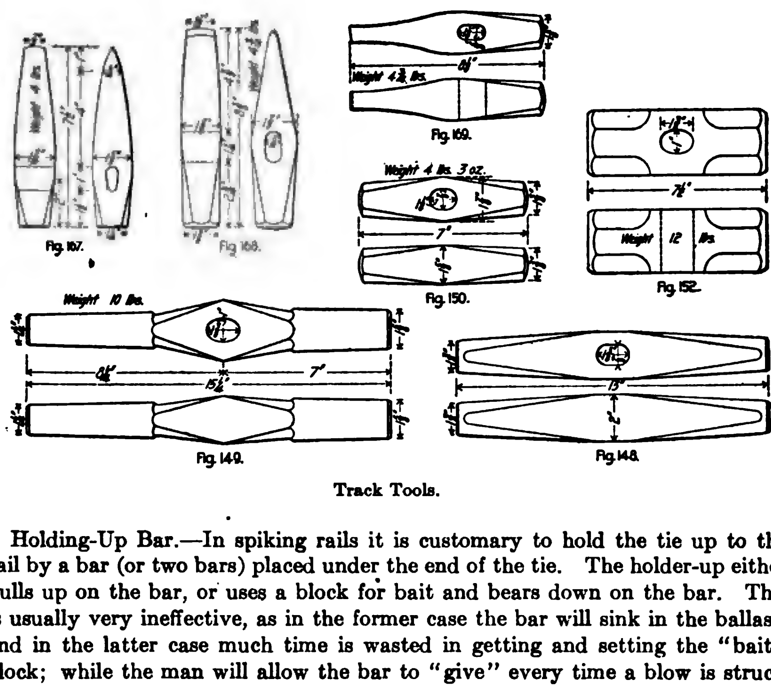
Hammers.—The spiking maul, Fig. 148, has a head 13 ins. long, 2×2 ins. square at the middle and tapering to 1⅜ ins. diameter at the ends. The weight is 8 to 11 lbs. Another form is shown in Fig. 149. The head is fitted to a straight wooden handle about 3 ft. long. The ballast or napping hammer, Fig. 150, is for breaking stone ballast; it is 7 ins. long, 1⅜ ins. diameter at the ends, and weighs 4 lbs. 3 oz. A lighter one, 6½ ins. long, weighs 3 lbs. The trackwalker's hammer, Fig. 151, has a long head with a short handle. One end is curved and either finished to a point or to a 1½-in. chisel edge. The weight is about 14 lbs. The sledge has a short heavy head, set on a long, straight handle. It is used for knocking out ties and for striking track chisels. Foremen should see that spike mauls are not used for such purposes, and that the sledge has a smooth face, or pieces may chip off and strike the man holding the chisel. The head, Fig. 152, is octagonal, with circular ends 2½ ins. diameter; it weighs 10 to 15 lbs.

Tamping Bar.—For tamping ballast (except stone or slag) a bar is used about 5½ ft. long, weighing about 12 lbs. Two forms are shown in Figs. 153 and 154, the latter being the form adopted as standard by the Roadmasters' Association. The bar is generally of ⅞-in. round iron, straight, with a flat piece 6 ins. long and 4 ins. wide, ½-in. thick at the edge, welded on at an angle of 24°, so as to strike well under the tie. The upper end should be flattened to a chisel edge 2 ins. wide. Some bars have the lower end bent, made ⅞-in. square, and having a tamping head 3½ ins. wide and ⅜-in. thick. A larger diameter gives a better grasp for the hand, and in some cases a gas-pipe handle is used to increase the diameter without increasing the weight.

Lining Bar.—For lining and throwing track, a straight bar is used, Fig. 155, generally about 5½ ft. long, weighing 22 to 30 lbs., and tapering from 1½ ins. square at the lower end to ⅞-in. diameter at the top. A weight of about 24

lbs. is sufficient in a well-made bar. The smaller end should be formed with a sharp diamond point, and the square (or lower) end should have a 1¼-in. chisel edge for about 3 ins. In throwing track, the flat end of the bar is driven into the ballast, and two men can take hold of it. In some cases the pinch bar serves as a lining bar, as it answers very well for the purpose and thus saves the expense and trouble of extra bars.

Pinch or Raising Bar.—This is used for heavy lifting and prying up, and for raising and holding a tie for spiking; also for slight raising of track, raising low joints, etc., although on some roads the track jack is used even for raising track very slight amounts. The bar, Fig. 156, is 5 ft. to 8 ft. long, weighing 26 to 40 lbs., and tapering from 1½ or 1⅝ ins. square at the lower end to ⅞-in. or 1-in. diameter at the top. The lower end is chisel-shaped for about 3 ins., but sometimes the front face is vertical, only the back face of the chisel edge being inclined, while in the lining bar, Fig. 155, both faces are inclined. The end of the pinch bar is sometimes straight, but is more useful when slightly curved outward so as to get a good hold, and form a fulcrum when prying.

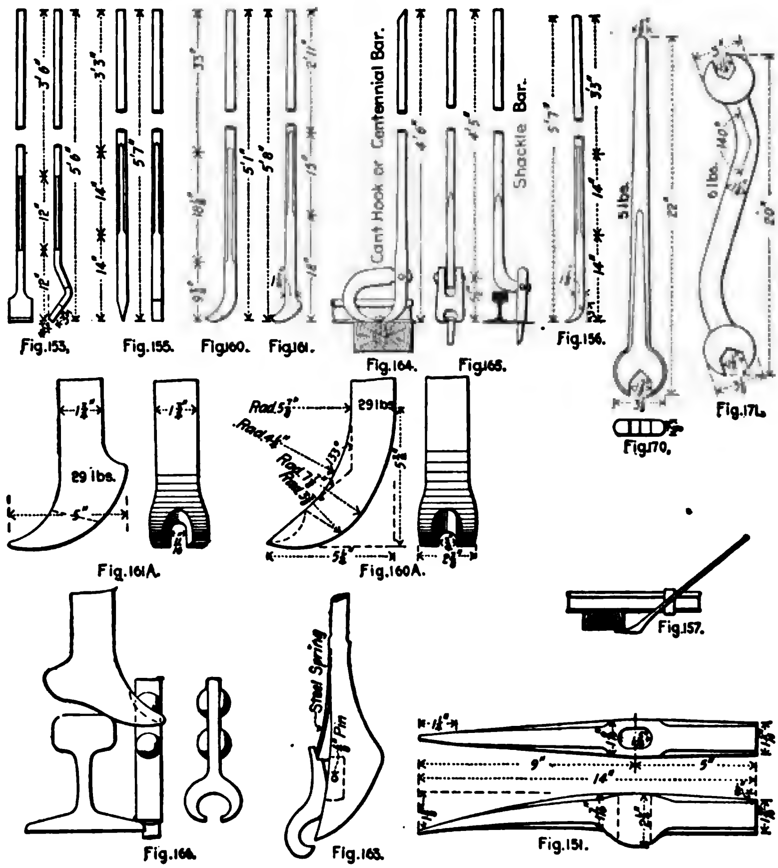


Track Tools.

Holding-Up Bar.—In spiking rails it is customary to hold the tie up to the rail by a bar (or two bars) placed under the end of the tie. The holder-up either pulls up on the bar, or uses a block for bait and bears down on the bar. This is usually very ineffective, as in the former case the bar will sink in the ballast, and in the latter case much time is wasted in getting and setting the "bait" block; while the man will allow the bar to "give" every time a blow is struck on the spike. A handy tool for this work is a holding-up bar, Fig. 157. This is a pinch-bar with an inclined sharp, chisel-edged lower end to fit under the tie, or to bite into its side. To one side of the bar is pivoted an angle-shaped piece, the horizontal part of which bears on the top of the rail, the bar being parallel with the rail. When the holder-up bears down on the end of the bar (which is parallel with the rail), he presses the tie up and the rail down, thus holding them firmly for the spiker. A shovel should never be used for holding up ties.

Bridge Bars.—Special bars are used for bridge work and two of these are shown in Figs. 158 and 159. The former is for sounding and moving timber. The latter is for pulling out headless drift bolts, the shackle being slipped over the bolt and a bait block put under the heel of the bar to act as a fulcrum.

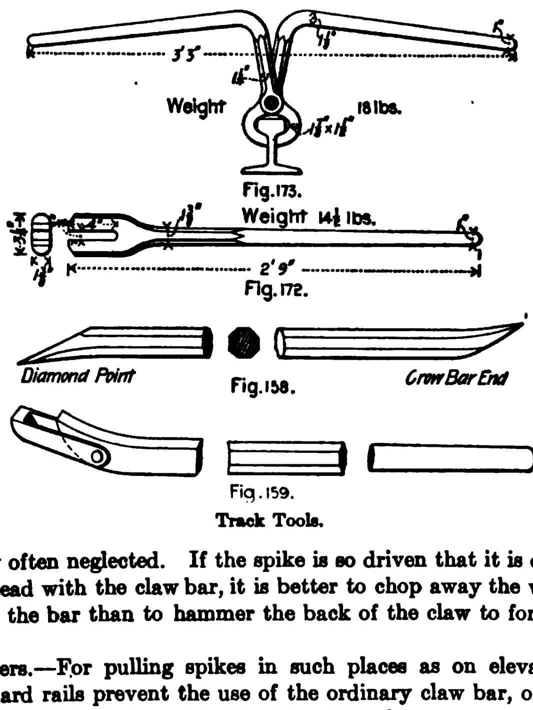
Claw Bars.—For pulling spikes a claw bar is generally used, ranging from 4½ ft. to 6 ft. in length, and weighing from 22 to 30 lbs. It is made in a variety of patterns. The body of the bar is usually about 1¾ ins. square at the ends,



Track Tools.

then 1¾ ins. octagonal and then of circular section, tapering to 1-in. diameter at the top. Three forms of claw bar are shown in Figs. 160, 161 and 162. The lower end is curved outward at an angle of about 45°, and has a broad chisel edge with a notch to take the neck of the spike, the edge being struck under the back of the spike head. The distance from the point of the claw to the back of the bar is about 4 ins., and a block or "bait" is put at the back to serve as a fulcrum. Sometimes the back of the bar has a curved projection or heel to avoid the use of "bait," the distance from point of claw to back of heel being about 5 ins. Another form of bar, known as the "bull-nose" bar, has the

lower end curved outward for a height of 6 or 8 ins., the radius being 5 or 6 ins. and the distance from edge of claw to back of bar being 4 to 6½ ins. The "gooseneck" claw bar has the lower end bent backward and then forward again in a curve so as to give a long leverage in pulling, but as the claw is then nearly flat or at right angles with the bar, it cannot be struck under the spike head so well as a claw of 45°. For this reason both kinds may be used if much spike pulling is to be done, using the straight bar to start the spikes and the "gooseneck" bar to pull them out. In this way two men with bars can do more work and injure fewer spikes than one man with a straight bar, and another man to hold "bait." The claw bar adopted by the Roadmasters' Association, Fig. 162, is 5 ft. long, weighs 30 lbs. and has a curved chisel point at the upper end. The claw end has a spread of 5¾ ins. from point to back of heel, 6 ins. above the point. In using these bars care should be taken not to bend the spikes, a matter



Track Tools.

which is very often neglected. If the spike is so driven that it is difficult to get hold of the head with the claw bar, it is better to chop away the wood with the sharp end of the bar than to hammer the back of the claw to force it onto the spike.

Spike Pullers.—For pulling spikes in such places as on elevated railways, where the guard rails prevent the use of the ordinary claw bar, or at frogs and switches, on bridges and at stations, where these bars cannot well be used, a special form of bar or a spike puller must be used. Fig. 163 shows a bar used on the South Side Elevated Ry., Chicago. It has a loose hinged tongue and is worked parallel with the rails. Two forms of bars used by the New York elevated railways are shown in Figs. 164 and 165. The Verona spike puller, Fig. 166, has a rigid jaw which is slipped under the sides of the spike head, and a vertical stem with two projections to give a grip for a heeled claw bar, the heel of which rests upon the rail. This weighs about 1 lb. The Justice spike puller has a hinged heel or "bait" which is swung down to give a high bearing or fulcrum when the spike has been started. The Welsh spike and bolt puller has pivoted claws whose rear ends form a toggle engaging with a wedge

in the heel of the bar, so that as the weight comes upon the heel the claws are forced to grip the spike. The movable jaws enable various sizes of spikes or drift bolts to be pulled.

Chisel and Punch.—Cold chisels used for cutting steel rails must be of good material, well made and well tempered, if they are to do much work. If too hard, they will break in use, especially in cold weather; while if too soft, they soon become dull and blunt. In winter it is well to warm them before using, and to strike the first few blows lightly. When only slightly dulled, and retaining their temper, they may be sharpened on the grindstone, but otherwise they must be sent to the shop. A good chisel should cut three or four rails, and the work should be done carefully, so as to damage the rail as little as possible. With good steel the chisel head will not chip under the blows. One chisel may

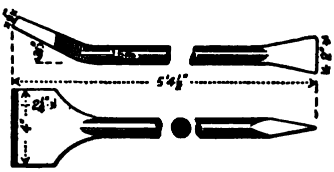


Fig. 154.—Tamping Bar.

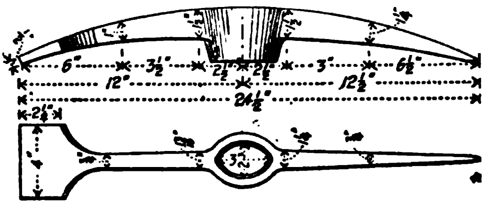


Fig. 174.—Tamping Pick.

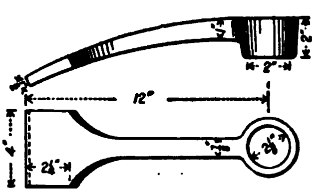


Fig. 175.—Tamping Puddle.

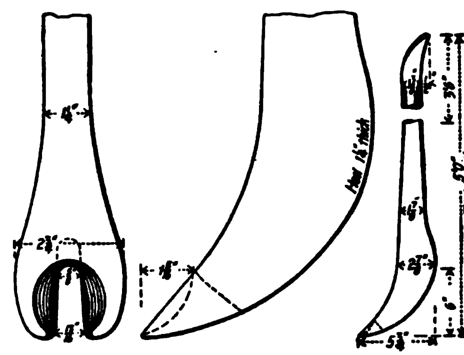


Fig. 162.—Clawbar.

Standard Forms of Tools Recommended by the Roadmasters' Association of America.

cut several rails, while another may lose its edge in cutting one rail. The striking hammer should have a smooth face and edges, or pieces may fly off and strike the chiselman. It is very bad practice to notch the rail with a chisel and then drop it on a block to break it, but sometimes the head is cut with a portable saw and the work finished with the chisel. Two forms of chisels are shown in Figs. 167 and 168, the latter being that adopted by the Roadmasters' Association. The handle should be about 18 ins. long, so that the man holding it will be out of the way of the hammer. A properly made and fitted handle should be used, and not any rough stick that is handy. The steel track or rail punch for hand use, Fig. 169, weighs about 4¾ lbs. The head is $\frac{11}{16}$-in. square at the cutting end, which has a beveled face; round punches are also used. Chisels and punches weigh about 5 lbs. each.

Wrench.—The ordinary track wrench is usually a steel-die forging, about 15 to 24 ins. long, weighing 5 lbs. The handle is of 1-in. diameter, having one end flattened out for the jaw, and the other end shaped to a chisel edge or tapered to ¾-in. diameter to put through the holes of rails and splice bars to bring them together. The jaws should have four sides, to conform in shape to a hexagon nut, and to fit a square nut. Figs. 170 and 171 show an ordinary and a double-end or S wrench. Long-handled wrenches are sometimes used, but with a handle more than 26 ins. long a careless man can apply such force as to strip the threads of the nut or bolt.

Rail Fork and Rail Tongs.—These are used for carrying and handling rails. The fork, Fig. 172, resembles a long wrench, but with a slot $\frac{3}{4}\times4$ ins. to receive the rail web or flange. The tongs are shown in Fig. 173, and are usually held by two men. The fork weighs from 12 to 15 lbs., and the tongs about 20 lbs.

Picks.—Ordinary picks have heads about 26 ins. to 30 ins. long, weighing 5 to 10 lbs., and are fitted with straight wooden handles about 3 ft. long. The best picks have heads of solid cast steel, which will not split in the eye, but those made in railway shops are usually of iron, with cast-steel ends welded on. The best refined iron should be used. A clay pick is about $1\times1\frac{1}{2}$ ins. at the eye. Both ends may have diamond points, or one end may have a chisel edge 1⅛ ins. wide. The "eyeless" pick is made of a steel bar, having a malleable-iron socket at the middle to which the handle is attached by a bolt. There should be three picks to every two men in the gang, to allow of their being sent to the shops for repair.

Tamping Pick.—This is used for tamping stone, slag and gravel ballast. It resembles the ordinary clay pick, except that one end has a flat tamping head. Fig. 174 shows the form adopted by the Roadmasters' Association. In another form the tamping end has the head gradually widening to shape from the eye, instead of having the plain shank with tamping head. The New York Central Ry. tamping pick for gravel is 24½ ins. long, with a ½-in. tamping head at one end, 4 ins. wide on the edge and 2¼ ins. deep. The shank is $\frac{3}{4}\times1$ in., and the eye 2×3 ins. It is of cast steel, and weighs 7 lbs. The tamping pick for stone is similar but with a head ⅝-in. thick and 3 ins. wide.

Tamping Puddle.—This is for tamping gravel, cinders, sand and dirt ballast, and resembles the half of a tamping pick. The weight is about 5 lbs. Fig. 175 shows the form adopted by the Roadmasters' Association.

Shovels and Forks.—Shovels of various forms are used for tamping and ditching, and for handling gravel, cinders, snow, etc. A good shovel is made from one piece of crucible cast steel, No. 12 gage, properly tempered, and having the straps strengthened by a taper socket for the handle, extending about 2 ins. above the blade. The top should also be strengthened to prevent the breaking or splitting of the blade. The blade may be about $11\frac{3}{4}\times9\frac{3}{4}$ ins. Tamping shovels have blades approximately square and flat, about 10×12 ins. The handle is about 30 ins. long. The shovel is about 3 ft. long and weighs about 7 lbs. In sand and gravel ballast the men will often tamp with the handles of their shovels instead of with the tamping bars, thus wearing and breaking the handles. A combined shovel and tamping bar, to provide for this practice, has an iron shield over the wooden handle, or a malleable iron head on the handle. Worn shovels may have the edges sharpened and be used for cutting weeds. Scoops are large full shovels, from 11×15 to 13×17 ins., for handling coal, cinders, snow, etc. For digging post holes, long-handled

shovels are used, having straight handles 4 ft. to 4½ ft. long. Post-hole augers may also be used by a fencing gang. Special forms of long-handled shovels are used for deep holes for telegraph poles, and various forms of ditching spades are also supplied where there is much tile ditching work. Large flat wooden shovels are convenient for handling snow in yards. For handling stone or slag ballast it is well to use forks (like stable forks), having eight to ten tines or prongs. These will eliminate the dirt or fine material which would be put into the track if shovels were used. The New York, New Haven & Hartford Ry. uses eight-pronged forks for handling stone ballast. There is one to each man, an ordinary shovel being also furnished to each man for handling the finer stone and for ditching, etc. The New York Central Ry. uses forks with 12 tines 13⅝ ins. long; they are closely spaced, to handle fine stone, and the width is 11 5/16 ins. The tines are curved to an ordinate of 3⅛ ins.

Post-Hole Digger.—This is a vertical bar with a wooden cross handle (or a tee-socket for the handle), and having at the bottom a set of vertical cutting blades which in some cases can be adjusted to diameters of 6 to 8 ins. The tool is worked with a combined vertical and rotary motion. Another form has two vertical arms pivoted at the bottom like a pair of shears, and each carrying a curved cutting blade like a large trowel. In ordinary soil one man in a ten-hour day can make from 100 to 200 holes 3 ft. deep. A post-hole auger has a spiral blade 4 to 10 ins. diameter (10 to 14 ins. for telegraph or other poles).

Scythes and Hoes.—For clearing the right of way, etc., scythes and special tools are necessary, according to the material to be dealt with. The railway scythe for cutting coarse grass and light weeds is slightly heavier than the common grass scythe. The bramble scythe is still heavier, and the brush scythe is shorter and stouter. The bush hook is a stout straight blade with a curved end, used for cutting bushes, and is fitted to a straight axe handle. The grub hoe is useful in cutting roots, grubbing heavy soil, etc., preparatory to new work, and is also handy in ditching and for removing tough grass and weeds from the side of the track. It has a single broad blade, like an adze, with an eye at the end for the handle; it weighs 3 to 6 lbs. The mattock is about 16 ins. long, with two 3½-in. cutting edges, one horizontal like an adze, the other vertical like an axe. The head weighs about 5 to 6 lbs., and has an eye to which is fitted a pick handle. The pick mattock has one end like a clay pick instead of an axe. Long-handled weed hoes are advisable where much weed cutting has to be done; they are operated much more easily than shovels and save much backache, thus enabling the work to be done quicker and to better advantage. This tool resembles a garden hoe, with a rather long blade set at about 150° from the handle. (Weed burners are described under "Maintenance.")

Track Gage.—This tool is to give the required distance between rail heads in tracklaying, and to test the accuracy of the gage on existing track. Gages with bars of seasoned oak or ash are used on nearly every road, and have an advantage over iron gages in that they are not appreciably affected by temperature and are not liable to become bent (and consequently inaccurate). On the whole, however, an iron gage is probably preferable, but unless the ends are insulated from the bar it cannot be used on roads having a track circuit for a block-signal system, as it short-circuits the current and affects the signals in the same way as the wheels and axles of a train. This has led to a more extended use of gages with wooden bars, but of better construction than the old styles.

In Fig. 176 are shown gages having steel ends riveted to a white-oak bar, and similar ends shrunk upon and riveted to a gas-pipe bar. To insure rapidity and accuracy in testing the gage of the track, one end of the tool has a steel fork with two lugs, so that when both lugs are in contact with the gage or line rail the bar will be truly at right angles to this rail and the other lug will give the accurate position for the other rail. This is a similar arrangement to that

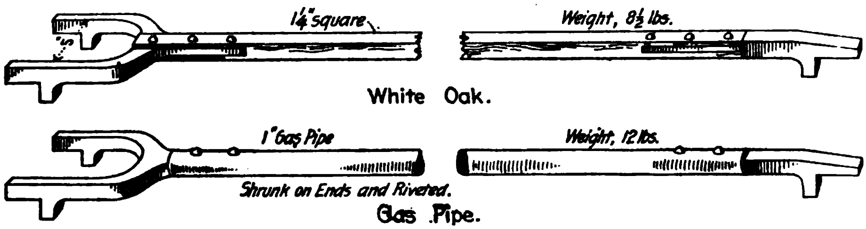


Fig. 176.—Track Gages.

of the Huntington gage. The "Circular" gage has at one or both ends an iron bracket curved to the radius of half the gage of track, so that it gives the correct width of gage even if the bar is not at right angles to the rails. The McHenry tool provides for widening the gage on curves. At one end are pivoted five plates of ⅛-in. steel, which are normally held up by a clamp. One plate is turned down for each 3° of curvature, giving a maximum gage of 4 ft. 9⅛ ins. for a 15° curve. On transition curves two plates are turned down for each 3°. The Louisville & Nashville Ry. uses fillers on the lugs to widen the gage of track ¼-in. and ½-in. In some cases the lug at one end is made of the width for guard-rail flangeway, so as to test and adjust the width. In the gage used by the Chicago, Burlington & Quincy Ry., the lugs are inclined to fit the heads of rails having inclined sides, measuring the gage at ½-in. below the top of the rail. The lugs are formed on malleable castings of L shape, ¼-in. thick, fitting the end and bottom of an ash bar 3 ins. deep and 1¼ ins. thick. Each is secured by three ¼-in. rivets which pass through a wrought-iron plate on top of each end of the bar. There is also a screw in the end of the bar. Track gages weigh about 15 lbs. On double track, a gage about 7 ft. long is used to test the gage relative to the center stakes.

Track Level.—This tool is for ascertaining whether the rails are in the same horizontal plane on tangents, or whether the outer rail has the proper elevation

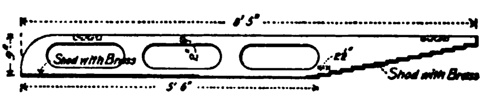


Fig. 177.—Track Level and Gage.

on curves. One form of the track level is a 1¼ or 1½-in. board, 5½ to 8½ ft. long, with a handle or hand-hole, and having a spirit level let into the top or side. One end is made with steps or offsets whose depth is equal to the elevation of outer rail for curves of different degrees, so that on a curve the spirit bubble is level when the bottom edge of the board is on the inner rail and the proper offset is on the outer rail. The board shown in Fig. 177 is of maple or white pine, 9 ins. deep for a length of 5½ ft., and then stepped in offsets ½-in. high and 2½ ins. long. This gives an elevation of 1 in. per degree up to and including

5°, and then ½-in. per degree up to a maximum of 7 ins. The offsets and the opposite edge of the board are shod with brass. The board is lightened by three openings about 5×12 ins., and has a spirit level at each end. The McHenry track level has at one end a steel blade moving in a vertical slot in the wooden bar. The edge of this is ground to an involute curve, and each face is graduated, the plate being adjusted by a thumbscrew. The level can be raised to give the full superelevation of 6 ins. while keeping the contact point of the plate constantly at the same relative position on the rail. The Sheffield duplex level has an arm pivoted at the center of the bar or board and resting against it. This has a spirit level on top, and the end forms a pointer moving over a scale on the side of the bar. When the arm is moved to set the pointer at any part of the scale, the spirit bubble will be level when the outer rail is raised the corresponding amount. These levels weigh from 10 to 16 lbs.

A level board or combined track gage, guard-rail gage and track level is often used. The one shown in Fig. 178 is a wooden board 1×4 ins., faced with a 3/16-in. iron strip. The length over all is 5 ft. 5½ ins. The gage of track and guard rails is measured respectively over the outside and inside of the lugs, as shown, the lugs being 2 ins. deep and 1⅞ ins. to 1⅝ ins. wide. At the middle of the board is a hand-hole, with a spirit-level tube set in the lower seat. At one end of the board is a plate sliding vertically in dovetailed guides, and held

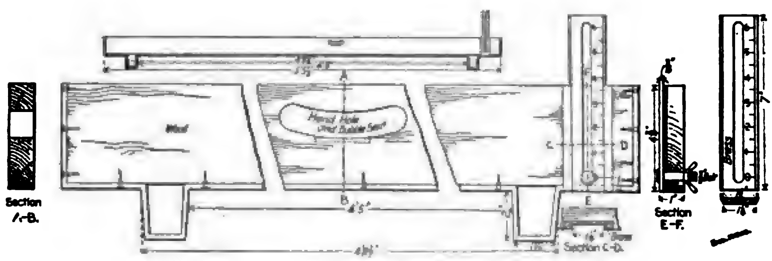


Fig. 178.—Track Level and Gage.

at any position by a nut on a ⅜-in. bolt. A graduated scale is marked on the slide, and in testing the superelevation of curves the slide is lowered to the amount of elevation required, this end of the level being then placed on the inside or low rail, and the outer rail then raised or lowered until the spirit-level bubble is in the center of the tube. By the attachment of a straight rod 3½ ft. long, held in position at the gage line by a semicircular arc, this tool is of assistance in lining tangents. By making the iron strip in two pieces, the ends are sufficiently insulated to enable the tool to be used on roads having automatic signals operated by track circuits. A less elaborate form has a graduated bar sliding in a vertical slot in the bar and held by a thumbscrew at the side. On the Southern Pacific Ry., foremen having curves of 5° and over are provided with a combined track level and elevation gage. For leveling one track with another, level boards 12 to 15 ft. long are used. The Boston & Maine Ry. gage is 14 ft. long, ⅞×6 ins., with strips ⅞×2 ins. along both sides of the bottom. One end rests on the rail of one track and the other rests on a leveling bob like a small screw jack (6 ins. high when closed). A spirit level is set on top of the board, and the board leveled; the opposite rail is then adjusted accordingly.

Leveling Boards.—These are used for sighting when raising or surfacing track or taking out sags in the grade line. In some cases three blocks of the

same thickness are used, placed on the rail at the point to be raised and at the already surfaced portion on each side. It is better to use a white board (with a horizontal black stripe a little above its center), and two blocks, each as high as from the bottom of the board to the top of the black stripe. The board is placed across the rails at a point where the track is at proper grade. One block is placed on the rail at the point to be raised, and the other the foreman places on the rail at a point already at grade. The track is then raised until the middle block is sighted in line with the top of the first block and the stripe on the board. The use of targets for this work is described under "Maintenance."

Tie-Plate Gage.—The general use of steel tie-plates has led to the introduction of special tools for fitting them accurately, so as to give an even bearing on the tie and correct gage when the rails are spiked through the holes in the plates. The Ware gage, used on the Buffalo, Rochester & Pittsburg Ry., is shown in Fig. 179. The bar (A) is of 1-in. gas pipe, having at one end a fixed head (B) and at the other end a sliding head secured by a thumbscrew clamp; this head is moved so as to give the correct position for plates of different sizes, the plate being set against the end of head (C), and its spur (D). The

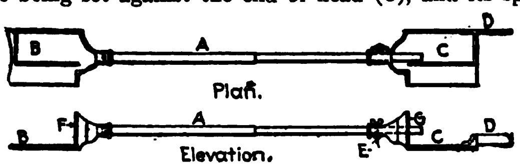


Fig. 179.—Gage for Setting Tie-Plates.

operations are described in Chapter 20, and machines for applying tie-plates are described in the chapter on Ties and Tie-Plates. The Curtis gage, used on the Boston & Maine Ry., is a wrought-iron bar $\frac{3}{4}\times2\frac{1}{2}$ ins., laid flat, and having at each end a rectangular frame $\frac{7}{8}\times1\frac{3}{4}$ ins. (on edge) with an opening $8\times5\frac{1}{2}$ ins. to fit the tie-plate, upon which is set a steel striking block. It is not adjustable, like the Ware device. A wooden bar with rectangular frame at each end is used to test the proper surface of the tie at the seats for the plates.

Rail Benders.—Rails should be bent to the proper curvature for all curves of 3° and over, using a proper rail bender to give accurate results. The ordinary jim-crow rail bender, Fig. 180, has a curved frame with hooked arms to hook over the rail head or flange, and pressure is applied to the rail head between the arms by a screw which is turned by a long-handled wrench on a fixed nut inside the frame or by a bar fitting into the holes of a capstan-headed screw. When the ordinate for the required curve is reached, the screw is slackened, the machine shifted along the rail, and the operation repeated. For heavy girder or T rails, the screw should bear against the web and head, a filler block being placed against the web. The hooked arms may be replaced by top and bottom arms extending beyond the rail; to the end of the top arm is pivoted a block whose face is shaped to fit the rail, and at the bottom of this is a lug to engage with a hole in the bottom arm. In this way the pressure is taken by the full height of the rail. These machines weigh from 100 to 200 lbs. for rails of 50 to 100 lbs. per yd. In other rail benders a bar or plunger takes the place of the screw, and the power is applied by an eccentric or cam, thrown by a long lever working in a vertical plane at right angles to the rail. Fig. 180 also shows a machine of this type; it weighs about 340 lbs. The Samson bender, for use on rails in the track, is a heavy cast-steel lever, having one end shaped

to fit the rail head, and the other carrying a capstan-headed screw (or hydraulic cylinder). At the middle is a projecting arm with a lug to engage the opposite side of the rail head.

The roller rail bender and straightener, Fig. 181, is very largely used, especially for heavy rails. It weighs from 400 to 800 lbs. The grooved rollers on

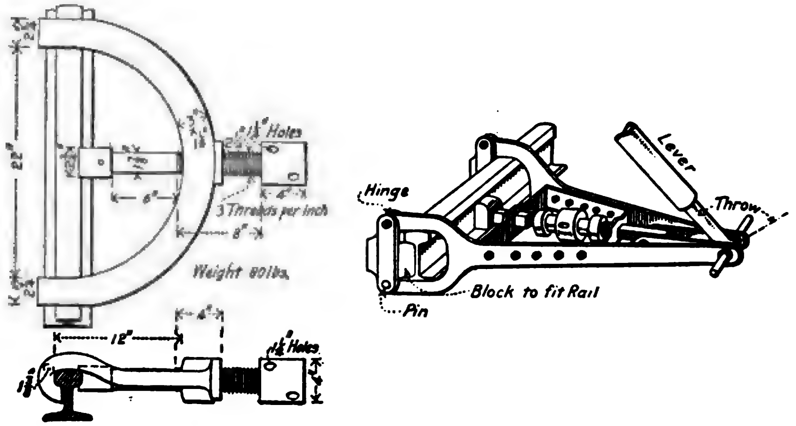


Fig. 180.—Rail Benders.

the arms fit the outside of the rail head, and a third roller on the bending bar fits against the inside of the rail head. The end of the rail is first bent as usual, by setting up the screw with a long wrench until the middle ordinate for the desired curve is obtained; then the inner roller is turned by a long lever or a cross-handled wrench, causing the machine to travel along the rail,

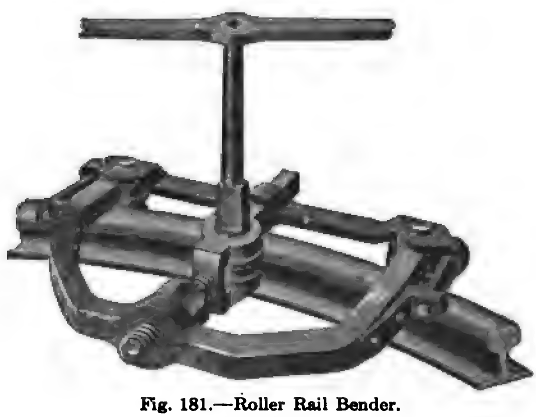


Fig. 181.—Roller Rail Bender.

thus giving a uniform curve from end to end. To straighten a rail, the machine is put on the outer side of the curve. It can be used on rails in the track to rectify curvature. The number of men required depends upon the weight of rail and the degree of curvature required. Where the rails are heavy or where a quantity of rails have to be curved at a yard for distribution over the division or for new track, it will be economical to fix the machine and run the rails through it. In this case the bending roll may be driven by power or by

a horse attached to a long sweep on the roller shaft. On the Nashville, Chattanooga & St. Louis Ry. the shaft has been driven by gearing from a gasoline engine, the shaft making 8.2 revs. per min. Such an arrangement could be mounted on a car. From 100 to 150 rails were unloaded, curved and loaded in a day. With the fixed machine operated by hand levers, and with a much larger gang, only 50 rails per day were handled. In bending rails by hand with 12 men and a fixed roller bender on the Franklin & Clearfield Ry. the rate was less than 50 per day. The plan was then adopted of pulling the rails through by a cable from the hoisting engine which was used in stacking the rails; in this way the number was increased to 175 and 225 per day. (See also chapter on "Maintenance.")

Hydraulic rail benders resemble the jim-crow in general form, but have a vertical hydraulic cylinder at the back of the frame to operate the ram or plunger which bears against the rail head. The ram may be run in and out for a few inches by hand, without pumping, thus allowing the machine to be readily placed on the rail and the ram brought up to its work, when a few strokes of the pump bend the rail to its desired curvature. The pressure is then reduced and the rail slid along for another application. The ram is graduated to show the extent of the bend and may have a loose head shaped to fit the rail head. The weight is from 200 to 275 lbs.

Angle Bar and Joint Press.—A jack or press is sometimes used to straighten angle bars which have become deflected or distorted. A hydraulic press has also been used for forcing the splice bars into position on the rails to insure a tight fit and uniform bearing. The latter is more particularly for use with deep girder rails.

Track Lever.—The track lever, Fig. 182, was the usual means of raising track until track jacks became of general application, and is still used to some

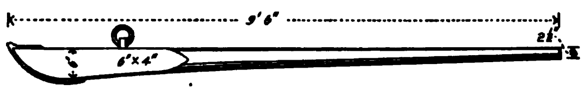


Fig. 182.—Track Lever.

extent. It consists of an oak pole with an iron shoe which is put under the rail or tie and blocking placed under the heel. Two or more men bear down on the free end. The method is clumsy and inefficient as compared with the use of jacks. It requires several men, raises the track by jerks, and makes it difficult to adjust the amount of rise accurately. Even when the proper rise is obtained, at least one man must hold the end of the lever until the ties are tamped, and he generally slacks up on it in spite of all care.

Track Jacks.—There are numerous varieties of track jacks, operated by ratchets, screws, friction clutches, hydraulic power, etc., and different makes of these varieties may be found on most roads. A good jack must be able to sustain a heavy weight on the lifting bar, be positive in action, durable in design, and capable of being relieved quickly of its load and removed almost instantly. The lighter they are the better, as long as they are of sufficient strength. The Roadmasters' Association has recommended a ratchet jack of not over 65 lbs. for general track work and a friction jack not over 95 lbs. for new ballasting.

	Capacity.	Height.	Lift.	Weight.
Light work........	5 tons	20 ins.	10 ins.	40 lbs.
Ordinary work......	10 "	24 "	13 "	60 "
Heavy ballasting....	15 "	30 "	20 "	105 "
Bridge work........	35 and 50	26 and 27	10 and 13	120 and 290

As track jacks are too high to go under the ties, they lift by means of a claw hung from the head of the lifting bar, the claw being close to the bottom of the jack when lowered. The jack therefore extends above the rail, and as it may be a dangerous obstruction to trains it must be made so as to be released promptly. For this reason trip jacks are used in track work, so that the bar can be instantly dropped and the jack removed in case of a train approaching. Single-acting ratchet jacks raise the load a full notch at each down stroke only; double-acting or compound leverage jacks raise the load half a notch at each up and down stroke. Lowering jacks (without trip release) are rarely used in track work, except on street railways. They are used in wrecking and bridge work, where a sudden (perhaps accidental) release would be undesirable or dangerous. There are some combined trip and lowering jacks. For use in tunnels, or close to platforms and retaining walls, a jack may be used having

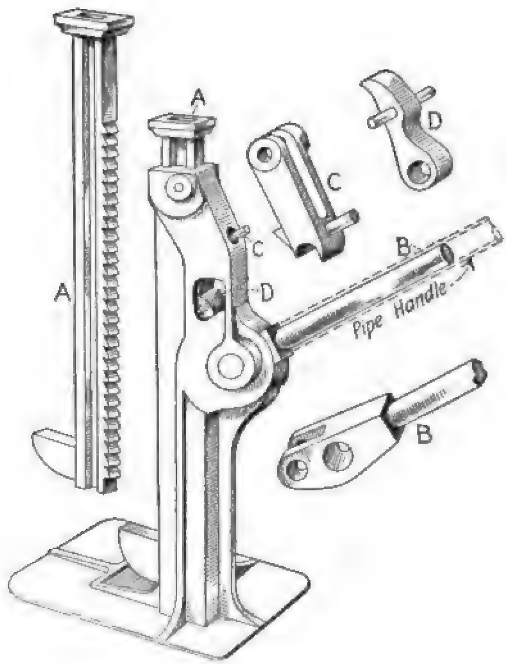


Fig. 183.—Ratchet Track Jack.

the claw at the side, the lever working parallel with the rail. For bridge work, screw jacks are largely used, the head being fitted with roller or ball bearings for easy movement. The handle operates a horizontal spindle with bevel pinion gearing with a bevel wheel on the threaded lifting bar; this bar works in a nut in the frame, and on the head is a cap with ball or roller bearings. Hydraulic jacks may be filled with 2 parts alcohol to 3 parts water in winter or 4 to 1 in summer. Water or kerosene should not be used, as water will cause rust and may freeze, while kerosene destroys the packing.

The ratchet jack in Fig. 183 has a frame of malleable iron, with a base 7×12 ins., as recommended by the Roadmasters' Association. All the other parts are

of crucible steel, with the exception of the loose pipe handle. The rack bar (A) has a sectional area of 1½ sq. ins., and is operated by the lever (B) and pawl (D), while the top catch (C) holds the bar in position at the height at which it is set. The load can be let down one tooth at a time when required, and can be dropped instantly and with certainty by the lower pawl, no independent trip being required. The 10-ton jack is 21 ins. high, with 14 ins. lift, and weighs 50 lbs.; a heavier make with 18-in. lift weighs 90 lbs. In the friction jack, Fig. 184, the link at the end of the working lever is coupled to a friction collar or lifting ring, which grips the lifting bar. Below this is the retaining ring. The rings are bored at an angle, so that when horizontal they grip the bar, but when lowered they release it. The 10-ton jacks for heavy ballasting, surfacing and general track repairs have a 15-in. lift; the height is 35 ins. when lowered, and the weight 90 lbs. A smaller size of the same capacity for short and heavy

Fig. 184.—Friction Track Jack.

lifts in surfacing has a 7-in. lift, is 22 ins. high, and weighs 55 lbs. For light surfacing, the jack has a capacity of 5 tons and a lift of 12 ins.; it is 31 ins. high and weighs 60 lbs. The load can be lowered instantly or slowly. A special form of jack is used for spacing ties in the track, when they have become shifted. Another special form is used for lining track. (See "Maintenance.") This has a separate base plate with ratchet, and when the track has been raised off its bed it can be traversed along this base plate.

The jack is now generally used for small lifts, as in surfacing, etc., as well as for large lifts in raising lengths of track, and also for work at frogs and switches. The jack should never be set on the inside of the rail; in such a position it is liable to derail a train, the pilot of the engine catching the jack and throwing it across the rail. If set outside the rail, the man in charge is in less danger, and less likely to forget to release and remove the jack when a train approaches, while even if the jack should be in place the engine would knock it away from the rail. The rules of some roads require that the jack shall always be used

on the outside of the rail, no excuse being accepted for contrary practice. The New York, New Haven & Hartford Ry. at one time went to the extreme of not issuing jacks to the section gangs, but having an extra gang to do all work requiring the use of jacks. Where much lifting is going on, flagmen should be sent out to warn trains to run cautiously.

Track Drills.—For drilling bolt holes in rails, ratchet and geared drills with automatic feed are generally used. One form is shown in Fig. 185. The frame should be fitted to the flange and not over the head of the rail, so as not to offer any obstruction to trains. The drill carrier should slide on the frame, so that the four or six holes of a joint can be drilled at one setting of the frame. In some of the ratchet drills the tool revolves with the movement of the operating lever in each direction, instead of in one direction only, as in the ordinary drills. They usually have four or six 1-in. bits. In several makes, the drill is driven by bevel gearing from a shaft in a vertical frame with a double crank handle at

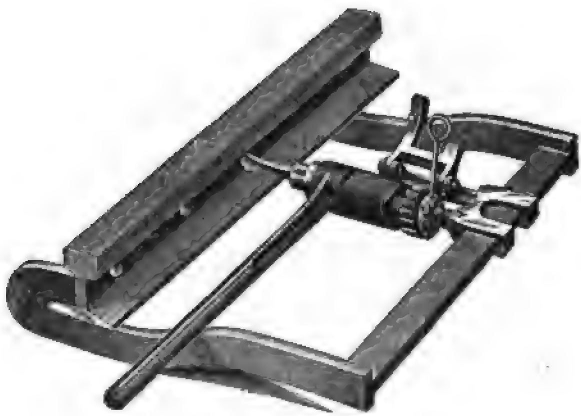


Fig. 185.—Track Drill.

the top. This frame is usually attached to the lower frame in such a way that it can be instantly lowered or swung back out of the way, without removing the lower frame or the drill. Work can then be resumed as soon as a train has passed, without the delay of adjusting the drill to an unfinished hole. In a drill of this pattern for small holes (¼-in. to ⅜-in.) for electric bonds, etc., the crank-handle shaft has sprocket wheels with chains to smaller wheels on the drill shaft. The New York Central Ry. has a drill car which runs on the rails and has the mechanism operated by a vertical engine taking steam from a locomotive. This can drill four 1⅛-in. holes in a 90-lb. rail in 3 mins. On the machine (as on some of the crank-handle drills) is a tool grinder.

Rail Punches.—The punch used like a chisel has been mentioned. Portable hydraulic punches are used to some extent, the jaw fitting over the rail and having at its back a vertical hydraulic cylinder operating the horizontal punch. An adjustable guide at the top of the jaw insures all holes being punched at the same height in the same size of rail. These machines weigh from 200 to 300 lbs. A vertical hydraulic punch for punching bond holes in rail flanges weighs about 90 lbs. Screw punches are sometimes used, those for heavy work requiring 2 or 3 men. A punch of this kind operated by 3 men, and weigh-

ing 80 lbs., has been used by the Buffalo Street Ry. for punching $1\frac{1}{8}$-in. holes in girder rails.

Rail Saws.—Rails may be cut by means of a cold chisel and hammer, or by portable saws clamped to the rail. The latter do better and quicker work, cutting a heavy rail in from three to ten minutes. Some machines have circular saws operated by hand cranks and gearing, the saws being 14 to 20 ins. diameter. They weigh 150 lbs. to 300 lbs. One is shown in Fig. 186. Another machine has a frame about 3 ft. high, with a reciprocating saw blade worked by two levers like a ditch pump or hand car. Its weight is about 120 lbs. A good thin oil, such as lard oil, is recommended for lubricating the circular saws,

Fig. 186.—Portable Rail Saw.

and soapsuds for the reciprocating saw. With these machines very clean cuts are made and very thin pieces can be cut when necessary. Their use is particularly advisable on first-class track, for heavy rails, and in fitting up frogs and switches.

Hand Cars.—These are for carrying the sectionmen to and from work. Most roads forbid their use for carrying rails, except in case of emergency. The cars should be as light as possible, consistent with strength and durability, may have wooden wheel centers, or pressed-steel wheels, and should invariably be fitted with a strong brake gear, generally operated by a treadle. Steel wheels are best for durability. These may be insulated, but wooden centers are generally required on lines where a track circuit is used, to prevent the cars from operating signals in the same way as a train. The cars will ride more easily if one of the wheels (not on the driving axle) runs loose on the axle. The

cars should be examined for repair every week, loose bolts tightened and bearings lubricated. Oil boxes should be frequently repacked, as the packing soon collects grit and sand. Roller bearings on the axles make the cars easier to propel. The car has a platform 6 ft. to $7\frac{1}{2}$ ft. long and $4\frac{1}{2}$ ft. wide, with a floor of matched planking, and the ends of the sills are extended to form handles. The wheels are ordinarily 20 to 24 ins. diameter. The weight is from 500 to 600 lbs., or 750 lbs. for bridge gangs. The car is generally driven by a lever or walking beam pivoted at the middle and having a cross-handle at each end, so that four men can work it, the spur-wheel being worked by a crank with a connecting rod from an arm on the walking beam. The spur-wheel gears with a pinion on the axle, the gearing being usually about $3\frac{1}{2}$ to 1. These cars will carry 10 or 12 men. There may be a tool box underneath, and for carrying large gangs there may be a plank seat along each side. A tool-grinder for sharpening drills, adzes, etc., may be clamped to the car.

The car in Fig. 187 weighs about 550 lbs., and has 20-in. steel-plate wheels on $1\frac{1}{2}$-in. steel axles, with a 4-in. bearing roller secured to the under side of each

Fig. 187.—Hand Car.

sill. The gears are $2\frac{3}{4}$, $3\frac{1}{2}$ and 4 to 1. The first is used where much power is required on account of steep grades, and the last where high speed is desired on level roads. The second is generally employed for ordinary work. When not in use the cars should be placed clear of the track. It is best not to leave them near road crossings; if left there, or at any distance from where the men are working, the wheel should be secured with a chain and padlock.

A track velocipede is a light three-wheel or four-wheel hand car, weighing 150 to 200 lbs. The operator propels it by a hand lever, treadle or both. In three-wheel cars, Fig. 188, the third wheel is carried at the end of an arm which is hinged, so that it can be folded back against the other wheels for convenience of shipment in a baggage car. These cars are used by roadmasters, inspectors, foremen, signal repairmen, etc., and on some roads by a man who rides over

the track daily instead of trackwalking. On the arm may be carried a tray for lamps or tools. The car may carry 1 to 3 persons and can be fitted with an odometer for measuring distances. Some velocipedes have frames of bicycle tubing, with wire-spoke wheels, and the bicycle style of saddle, handle bar and driving gear. These weigh only 70 to 100 lbs.

In order to facilitate the work of the sectionmen by eliminating the work of driving the hand car and giving greater speed, several roads are introducing cars propelled by gasoline engines. Such a car with a 7-HP. engine will weigh 1,000 to 1,200 lbs., and can be run at 12 or 15 miles per hour. Similar cars for the use of roadmasters, signal inspectors, or other division officers, weigh

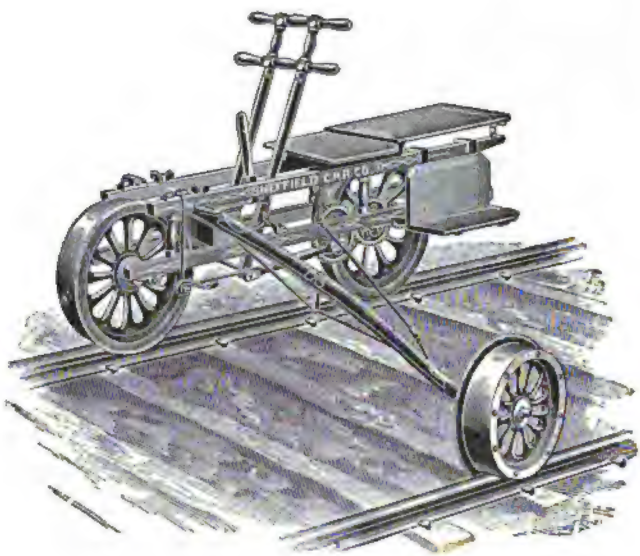


Fig. 188.—Track Velocipede.

from 800 to 1,600 lbs., and have engines of 6 to 15 HP. Specially light machines with 4-HP. engines weigh only about 500 lbs. Ordinarily a 5-gal. tank of gasoline is used, with a 25-gal. storage tank for very long runs. These cars can be run at 25 to 35 miles per hour. (See Track Inspection.) Section cars and velocipedes have been operated by sails on some western roads, but great care is required in operating them.

Push Car and Rail Car.—The push car is a platform car not fitted with propelling gear, and is used for carrying rails, ties, gravel, earth, supplies, tools, etc. The car in Fig. 189, with a platform 7×5½ ft., and four 20-in. wheels, will weigh 450 to 500 lbs. The rail car (see Tracklaying) has no platform; there are two side sills (to which the journal boxes are attached) and three or four cross timbers faced with iron. At each end are two rollers to facilitate unloading rails. A rail car 8×6 ft., with sills 4×8 ins., wheels 16 to 20 ins. diameter, 2¾-in. axles, and a carrying capacity of 10 to 12 tons, will weigh about 1,200 to 1,600 lbs. The wheels are about 5½ ins. wide on the tread, and the wheel base is 4½ ft. Sometimes two diagonally opposite wheels run loose on

the axles. A plank bottom may be nailed to the under side of the middle cross sills to form a box for tools or supplies.

Wheelbarrows.—These may be of wood or iron, the former being more readily repaired on the section. They should be substantially built, with strong axles and bearings, and will require occasional oiling. In ditching work, a wheelbarrow with grooved wheel to run on the rail is sometimes used. The "track-barrow" has a wide grooved wheel with the axle set somewhat diagonally so that the man can walk at one side of the rail instead of astride of it, the center line of the barrow being at a slight angle with the rail. It can be used on or off the rail.

Flags.—The ordinary flag is not reliable as a signal when the staff is stuck in the ground; if the weather is calm it hangs limp, while the wind may blow it parallel with the track or wrap it round the staff. This may be remedied by having it attached to a staff at each end, or the staff may be fastened horizontally to a post 4 ft. high, 8 ft. from the rail. In the Tallman device the flag is

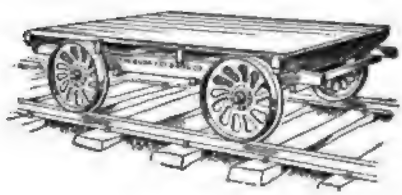


Fig. 189.—Push Car.

wound on a roller in a cylindrical case having a slot for the flag. This case is hinged at one end to the staff and when not in use folds against it (with the flag inside). When in use the case is horizontal and the flag displayed. Some roads require a flagman to hold the flag always in his hand, but where a flagman is not stationed, a flag with two staves, or with some means of keeping it displayed, should be used. Iron flags or targets have been used. Flags should be kept as clean as possible, and replaced when so torn or dirty as to be unreliable as signals. When not in use they should be rolled up and tied with string. Red and green are the usual colors, but on the Southern Pacific Ry. the sectionmen and bridgemen use red and yellow flags.

Lamps.—The ordinary railway lamps or lanterns are of use as signals, but not of much use for lighting work on the track. They should be kept well trimmed and filled, and placed on a shelf out of the way so as not to be broken in handling the tools. A few spare globes should be kept on hand. The oil cans (usually of 2 gallons capacity) should be set in a wooden box or tray filled with sand, and some oil should be kept on hand when the cans are sent to be refilled. Red and green (or yellow) lamps must be provided for signaling purposes. The night trackwalker may carry a lamp having red and green glasses mounted in an interior revolving cylinder; this is operated by the lamp handle or bail and enables the man to use one lamp for signaling. Large hand lamps or oil torches for work at night or in tunnels will be provided as required.

Miscellaneous.—Heavy garden or farm rakes are used for clearing up brush, trimming station grounds, etc., and wooden rakes may be used if hay is made from the grass cut on the right of way. Ordinary flat corn brooms are used for clearing snow from switches and frogs, cleaning ties after adzing for new rails, and also for sweeping out the section house. There are also special tools

for lining curves, setting out switches, etc. These are usually purchased by roadmasters for their own use, and are not supplied by the railways. A portable emery-wheel tool grinder may be clamped to a bench or to the hand car, and will do better work than grindstones for sharpening drills, chisels, scythes, adzes, etc. Being portable, it can be used on the work.

CHAPTER 15.—SIGNALING AND INTERLOCKING.

The installation and maintenance of the signal equipment is frequently under the charge of the maintenance-of-way department to a greater or less extent, and the general principles and practice may be appropriately considered. The details of the mechanism, apparatus and operations controlling the various movements of trains, however, would occupy far more space than is now available. The fixed signals governing train movements, independent of the switch-stand targets, may be classed as route signals, train-order signals and block signals. The first are used at turnouts, junctions, crossings, etc., to indicate for which track or route the switches are set. Train-order signals are located at stations, to indicate whether a train is required to stop for orders as to its movements. Block signals take the place of train orders, and indicate whether the block sections into which the line is divided are clear or occupied by other trains. Train-order signals may be used at stations as supplementary to the block signals. Interlocking signals comprise both switch and block signals, and, properly, they should not be separately classed. In this country, however, many interlocking plants are installed at crossings, etc., on lines where the block system is not in force, and this has resulted in creating a distinction between block and interlocking signals. In effect the limits of the interlocking plant enclose an isolated block.

Train Dispatching.—Under the train-order or train-dispatching system of operation, the dispatcher on the division issues telegraphic orders to the train crews to run between certain points, stopping at specified places for further orders or to allow other trains to pass in the same or opposite direction. He can stop the train for orders at any station by notifying the telegraph operator or station agent to display his train-order signal at the "stop" position. Following trains are required to be held a certain number of minutes apart, forming a time interval. This cannot always be maintained, as the first train may break down or run more slowly than was intended, while the second train may run faster and overtake the former. The former would send back a man with a lamp or flag in case of stopping or losing time, but this is very ineffective protection. There is also liability for confusion and misunderstanding in giving or receiving the numerous orders. The system is inadequate and unsafe for the handling of fast trains and heavy traffic under modern conditions.

Block System.—Under this system, which is the only one insuring safety to railway traffic, the line is divided into sections or blocks, and only one train is allowed in a block section. The limits of these are marked by signals, so that the trains are periodically advised as to the safety of the line ahead. The great advantages are facility and safety of operation, for as no two trains are normally admitted to the same block, a "space interval" is maintained between all trains, so that collisions are impossible. On single-track roads it must, of course,

protect a train from other trains running in either direction. With the "absolute" block system no train must be admitted to a block section until that section is clear or empty. The "permissive" block is a modification under which a second following train may be admitted after a certain "time interval," a caution being given to proceed carefully as the block is not clear. While this may be necessary in an emergency, it is dangerous for regular work, as it at once eliminates the great element of safety due to the "space interval." It has been adopted in some cases for freight trains only, with a view to facilitating traffic, but in some of these cases it has been abandoned eventually, since ample facilities and much greater safety can be afforded by the "absolute" block system. The block system is extensively adopted on both single-track and double-track lines.

The length of the block sections varies greatly, depending upon the amount of traffic, the curvature, switches, stations, passing places, etc. The block signals may be operated under three different systems: 1, Manual, without locking; 2, Controlled-manual, or lock-and-block; 3, Automatic. In the manual or telegraph-block system, a tower or cabin is erected at the end of each section and is occupied by a signalman, except that at stations the telegraph operators operate the signals. There is telegraph or telephone connection between adjacent towers or stations, and each signal is operated by the signalman in accordance with instructions given by the next man in the rear and in advance; or by the dispatcher. In the controlled-manual system, each signal is controlled from the tower in advance, so that a man at one tower cannot show a "proceed" signal until the signal is released by the man at the next tower. The "proceed" signal is automatically returned to and locked at "stop" by the entrance of a train into the block section, and cannot be released until the train has passed out of the section. In the automatic system the block signals are operated automatically by the trains, by means of electrical connections or track instruments. A wire circuit or rail circuit may be used. The latter is general and has the advantage that a broken rail, open switch, etc., will cause the signals to indicate "stop." Where a rail circuit is used, the rails of each section are connected by bond wires at the joints, and insulated joints separate the rails of adjoining sections. (See "Rail Joints.") Sectionmen must be careful not to bend or cut the wires in doing their work.

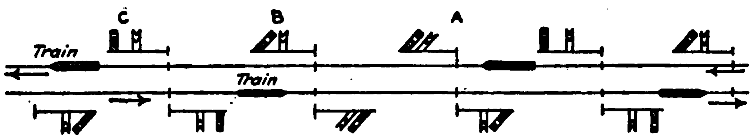
Manual and Controlled-Manual Systems.—To illustrate the operation of these systems, we may consider two adjoining sections A–B and B–C. In the plain-manual or telegraph-block system, the man at B is advised from the block station A that a train has passed into the section A–B. If advised by the man at C that section B–C is clear, B lowers his signal to admit the train into that section. When the train has passed he puts the signal in position to stop a following train, and does not lower it until informed that the previous train has passed out of the section at C. With permissive blocking, or in the emergency of the first train not reaching C in proper time, a second train may be allowed to enter, with instructions to proceed cautiously. This system lacks the safeguards which are essential to the operation of heavy traffic, especially in view of the liability to carelessness, mistakes, etc., in transmitting or obeying instructions. Where the blocks are the full distance between stations, intermediate automatic signals may be used to avoid a long spacing between trains, as noted below. The plain-manual system is often used without distant signals, which is a defective feature.

In the controlled-manual system, operation of the signal at the entrance to a block is controlled electrically by the signalman at the next block station. At each block station there is a track circuit of 60 ft. or more, which is used to operate an electric slot and automatically return the home signal to the "stop" position when the first pair of wheels has entered the track-circuit section. Each block station has two instruments for each track, one for the block section in the rear and the other for the section in advance. In other words, each block section has an instrument in the tower at each end, and these are connected electrically with each other and with the operating levers. The operator at the outgoing end, B, controls the lever by which the operator at the incoming end, A, lowers his signal to admit a train to the section A–B. When the train is in the section, this signal at A is automatically returned to the "stop" position, and it can neither be unlocked nor lowered until the train has passed out of the section. If a following train arrives it must wait at the "stop" signal, but if the preceding train fails to pass out of the block within a specified time, the second train may be given a "caution" card authorizing it to proceed slowly. On some roads, one freight train may follow another after waiting five or ten minutes (if the signal is not cleared in the meantime). This is permissive blocking, however, and it is never safe and rarely necessary.

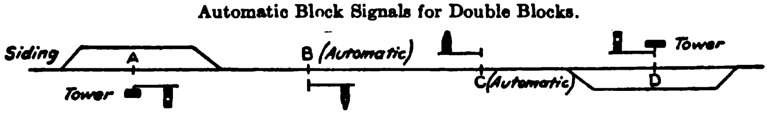
Automatic System.—In this system the train sets each signal at "stop" as it passes. It releases the signal behind, which then automatically returns to the "proceed" position. The system is adapted for all kinds of service. It is economical for lines with light traffic where the expense of the manual system and operators would not be warranted, but where some protection is desired. It is also specially economical where the traffic is very heavy and the blocks are so short that the expense for complete manual plant and operators would be very heavy. The liability to get out of order is very remote. The signals are necessarily permissive, as in case of a signal failure a train must pass the "stop" signal, or the traffic would be blocked indefinitely. The rule is that a train may pass the "stop" signal after waiting a specified time, proceeding cautiously to the next signal. Automatic signals may be operated by electricity alone or by a combination of compressed air and electricity. In the former case, each signal has motors or electro-magnets operated from batteries which are charged by a line wire or are renewed at intervals. In the latter case, the valves of air cylinders attached to the posts are operated by the electrical connections, the actual movement of the signal (and of the switch, in interlocking plants) being effected by the air, which is carried in a line of 3-in. or 4-in. pipe laid along the side of the roadbed or buried between the tracks. The pressure is usually 80 to 90 lbs. The automatic system is extensively used, not only for light traffic, but also for lines with very heavy and fast traffic. The ideal system for controlling trains on lines with heavy traffic and high speeds was suggested as follows by Mr. E. C. Carter, Chief Engineer of the Chicago & Northwestern Ry., in a report prepared for the International Railway Congress of 1900: "(1) Interlocking plants at all points where there are switches on the main tracks, the home or advance signals being electrically slotted with a track circuit through the succeeding block, the towers to be supplied with indicators to give information regarding trains in the adjoining blocks. (2) Automatic block signals placed as required to properly space trains moving between the interlocking plants. Such a system will admit of

the heaviest traffic movement, with the greatest safety, with the least detention, and at least cost for protection."

With blocks less than a mile in length, indications for two blocks may be given at each block station. In one arrangement there are two distinctive signals at each block station. As a train passes into a block, B–C, it throws both signals at B to "stop," protecting its rear. At the same time it releases one of the signals of the section behind, at A. In another arrangement one signal gives three indications: "stop," "clear to next signal," "clear to second signal." With the overlap system the train entering a block does not set the signal until it has proceeded a certain distance. Thus a man who had failed to see or obey a distant signal would have a chance to stop between the home "stop" signal and the train ahead. In the automatic-signal system on the Boston & Maine Ry., the blocks are about 4,000 ft. long (less for dense traffic and more beyond suburban districts). At large yards they cease at the outlying home signal of the interlocking plant, and commence again at the advance starting signal of that plant. On single track the signals are staggered and overlapped a distance sufficient to provide ample room for stopping a train. The double indication is used, each signal having two arms on the same post. The upper (home) arm is red with a white stripe, and when lowered it indicates that the block, A–B, beginning at this post is clear. The lower (distant) arm is forked and is painted yellow with a black fish-tail stripe. When this is lowered it indicates that the block B–C (beginning at the next post) is also clear. Thus an engineman is advised at each post as to whether he has one or two clear blocks ahead. The arrangement is shown in Fig. 190.



Automatic Block Signals for Double Blocks.



Combined Manual-Controlled and Automatic Block System.

Fig. 190.—Automatic Signals for Regular and Auxiliary Blocking.

Combined Manual and Automatic System.—A combined manual and automatic block-signal system is employed on some roads to facilitate traffic on single-track lines. The Cincinnati Southern Ry. has a system of this kind. The controlled-manual signals at the ends of the blocks govern opposing trains, while intermediate automatic signals govern following trains and maintain the necessary space interval between them. A train finding an automatic signal at "stop" waits one minute and then proceeds under control, but no train must pass a manual signal when at "stop." The signalman at one end of the block can admit several trains while his instrument is unlocked from the other end, but each successive train is held by this signal being automatically locked at "stop" until the preceding train has passed the first automatic intermediate signal. This system is considered to have increased the traffic capacity by 30% as compared with the telegraph-block system having blocks 4 or 5 miles long. A somewhat similar system is in use by the Illinois Ceutral Ry. on busy

single-track lines, where it was considered that automatic signals would not facilitate the movement of opposing trains or of inferior and superior trains in the same direction. The object of the intermediate signals is to avoid the use of permissive blocking in long blocks, and there is one signal for each direction of traffic. Each block signal is controlled by a slot apparatus connected with the track circuit between this signal and the opposing intermediate. In the plan, Fig. 190, the block section A–D has the two regular manual-controlled signals A and D and the automatic intermediate signals B and C. The slot control for A is the track circuit A–C, and that for D is the track circuit B–D. When the man at D releases the lock, signal A can be lowered and the train will enter, the signal being automatically returned to the "stop" position. If there is no train in B–C, signal B will indicate "proceed"; but will be automatically set at "stop" as soon as the train passes. While the train is in B–C all the four signals are locked at "stop." After it has passed C, however, the man at A can again lower his signal, admitting a train into A–B. The distance A–D is preserved between opposing trains, but following trains may be spaced the distance A–B, B–D.

Train-Staff System.—This is a modification of the controlled-manual system. In its simplest form each block section had a small bar or staff which must be carried by any train moving over the section. This, however, required trains to run alternately in opposite directions. With the electric train-staff system, there are several staffs to each block, and these are placed in cases at either end. The cases are electrically connected, each one controlled by the signalman at the other end. When a train wishes to proceed from A to B, the signalman at A notifies B, who (if the block is empty) releases the instrument at A, so that one staff can be taken out. When this is removed, both instruments are automatically locked, so that no other staff can be removed at A or B. When the train reaches B, the staff is delivered to the signalman, who places it in the instrument and thus restores the apparatus to its normal condition. Either one of the men can then release the other's instrument, allowing the latter to remove another staff. In some cases a metal tablet is used instead of a staff. Semaphore signals are used at the block stations, but cannot be lowered until all staffs are in place. They may be automatically restored to the "stop" position. The staff can be exchanged at block towers by trains running at considerable speed; either by apparatus on the engine and the track, or by enclosing the staff or tablet in a pouch having a large brass ring through which the engineman or fireman thrusts his arm as the train passes. Thus at B the train would drop the A–B staff and pick up the B–C staff, supposing the signal to indicate "proceed." The train-staff system has been used in a number of cases for isolated single-track blocks, to protect and facilitate traffic at long bridges, tunnels, etc., or stretches of single track on double-track roads.

Signal Equipment.—With comparatively slow trains, the only signal necessary would be the "home" signal at the entrance to each section. With high speeds it would be impossible to stop the train at a signal after it came in sight. A distant signal is therefore provided, to warn the engineman of the position of the home signal. When the distant signal indicates "clear," the engineman knows that the home signal is also at "clear" and that he has a clear track through the block section which he is approaching. The other position of the distant signal does not indicate "stop," but only "prepare to stop at the home signal." It indicates to the engineman that the home signal is at "stop," and

while the latter may be moved to the "clear" position before he reaches it, he must get his train under control ready to stop at the home signal if it has not been cleared. Trains held at a home signal are often allowed to pull past it so that the signal will protect the rear of the train, in which case an "advance" signal is put about a train-length beyond the home signal, so as to indicate to the engineman when the block is clear. On single track, however, trains must not pass the home signal until it is clear. The arrangements of automatic distant signals have already been referred to. Manual signals are usually kept at the "stop" position except when it is necessary to give a "clear" indication to a train, but automatic signals return to the "clear" position as soon as a train has passed out of the block.

The signals in general use are of two types: 1, The semaphore signal, consisting of an arm pivoted to a mast or post, and giving different indications by different positions; 2, The disk signal, the post carrying a "banjo" box having an opening at which a colored disk appears. The signals may be placed at the side of the track, or on bridges spanning the tracks. The arm is about 8 ins. wide and 4 ft. long, and projects on the right side of the post. It is set in a spectacle casting pivoted to the post; this casting forms a counterbalance and has 6-in. or 8-in. colored lenses which move in front of the lamp as the arm moves. The semaphore type is by far the most generally adopted. It is used for both block and interlocking signals, and with both the manual and automatic-block systems. The disk type is used only for automatic-block signals. The signals are carried on wooden posts, or on steel posts of tubes, or built up of angles and lattice bars. Block signals are usually about 20 or 25 ft. above the track. At interlocking points the height may be 30 or 40 ft. A bracket post for signaling two tracks, as on four-track lines, carries a platform supporting two posts 5 to 10 ft. high. Dwarf or low signals are commonly used for switching and reverse or back-up movements. There should not be more than two arms on a post, and these should be at least 6 ft. apart. An exception to this is a small arm placed low down on the post and governing low-speed or secondary movements.

Two positions of the semaphore arm are usually employed. The horizontal position of the arm means "section occupied, stop." Any position below the horizontal (usually 60° to 90°) indicates "section clear, proceed." In some cases a third position is introduced for permissive blocking, the arm being inclined 60° below (or above) the horizontal to indicate "section occupied, proceed under control." The arm then stands in a vertical position to indicate "section clear." It is better to have only two positions, and to issue a clearance card cautioning the train to proceed carefully, when it is imperatively necessary to send it on without waiting for the section to be cleared. A three-position signal, however, may be used to advantage with double blocks, as already noted. When horizontal, it indicates "stop"; when inclined, it indicates "clear to next signal"; when vertical, it indicates "clear to second signal." It is thus a combined home and distant signal. There is a growing tendency to have the arms move upward instead of downward from the horizontal to the inclined and vertical position, and on busy roads the combination of two arms and lamps may indicate whether the train is to proceed on a high-speed or low-speed track. It is not advisable to give too many indications, which may confuse an engineman who has to recognize their meaning instantly.

Semaphore signals usually have the face of the arms of home and advance

signals painted red with a white square near the end, while those of distant signals are painted green with a white square or V stripe, the end of the arm being notched or fish-tailed. Some roads use yellow with a black V stripe for distant signals. Others use yellow with a black square or black fish-tailed stripe for the running face of all signals. The object of this is to have the indication of the signal given by position and not by color. With disk signals a red disk for the home and a green disk for the distant signal is the usual practice. Signals at interlocking plants are almost invariably of the semaphore type, but where this type is also used for block signals, a distinctive form is sometimes adopted by making the arms of the latter pointed, with V stripes. This is done for the reason that an enginemen must never pass a "stop" signal at an interlocking plant unless he has definite and positive orders and a "clearance card" from the signalman. An automatic-block signal, however, may be out of order, and if it is not "cleared" in a few minutes, the train may proceed carefully, expecting to find a train, broken rail, etc., in the section. On the New York Central Ry., the system is as follows: 1, Home signal of controlled-manual system; square-end red blade with a white stripe. 2, Distant signal; forked or fish-tail yellow blade with a black V stripe. 3, Special permissive signal; green blade of the same shape, with a white V stripe. 4, Automatic home signal; red arm with a pointed end and white V stripe. 5, Train-order and telegraph-block home signal; red blade with a rounded end and curved white stripe. On this road the signals are painted every three months. The back of the blade is usually painted white, with a black vertical stripe.

The night indications are given by colored lamps. The old plan was to use red for "stop," white for "proceed," and green for "prepare to stop" on the distant signal. Owing to the confusion of white signal lights with street lamps and other lights in towns and cities, and to the possibility of a "stop" signal indicating "proceed" by the breaking of the red lens, the most approved system now is to use the green light for "proceed." This, however, has made necessary a new indication for the "prepare to stop" position of the distant signal, and two methods have been adopted: (1) To use two lenses (with one lamp), the signal showing a green light for "proceed" and a green and red light side by side for "prepare to stop"; (2) To use a distinctly yellow (not white) lens. The latter is preferable, as it avoids the use of a double light for one signal. The former was introduced by the Chicago & Northwestern Ry., and the latter by the New York, New Haven & Hartford Ry. In disk signals, the lamps show a light through an opening in the case, colored lenses inside being moved in accordance with the movement of the disk. A purple light is sometimes used for "stop" on minor signals, such as the low or "dwarf" signals for secondary movements or for reverse movements through interlocking plants. It is also used for the "dummy" posts indicating unsignaled tracks where bracket posts are used. To indicate whether the signal lamp is burning, a small opening with a frosted white glass is put at the back of the lamp, and shows only when the signal is at "stop." The lenses are usually 5 ins. or 6 ins. diameter, with a 2-in. backlight. (See Chapter 7, "Lamps.") The colored glasses in the spectacle casting of the semaphore arm are 6 ins. or 8 ins. diameter.

The home signal is usually 50 to 200 ft. from the point it governs, and the distant signal 1,500 to 3,000 or even 5,000 ft. beyond. Very long spacing, however, requires reliable compensators, which are few and expensive. Derails

at crossings are 300 or 400 ft. from the crossing, or 150 to 300 ft. from back-up derails (see Chapter 9, "Track Crossings"). Signals on bridges spanning the tracks should be set directly over the tracks governed. Those on posts should be at the right-hand side (left-hand when trains keep to the left). If tracks are too close together for the signal to be set at the side, a bracket post should be set at the right of the outer track. This has a platform carrying posts of different heights, the highest indicating the high-speed route. If there are two tracks there will be two posts on the platform, but if the inner one is a sidetrack and not signaled, then the low post corresponding to this track will have no arm and will carry a purple light at night. When the signals are at stations, the two arms are often mounted on opposite sides of the top of one post in front of the operator's office. It is much better to have each signal on its own post at the proper end of the station, thus protecting trains from the rear. All main-line switch signals should be included in the block system. If for economy or other reasons this is not done, then a target should be used, entirely distinctive from the block signals.

Block Signals on Electric Railways.—With the increase in length of electric interurban railways and the increase in the speed and traffic, methods of controlling the movements of cars become necessary, and failure to introduce such methods has been the cause of many serious collisions. Most lines of this class are now operated on the train-dispatching or train-order system, with telephone communication. The crews report by telephone at stations, passing sidings, etc., while connections on the poles at frequent intervals allow of special communication in case of emergency. The dispatcher, however, has ordinarily no means of calling the train crews, as is the case on steam railways. With the Blake system, semaphores and lamps are placed along the line and are under the control of the dispatcher, who can thus notify the men to call for orders. This is not a block-signal system. Block signals are as yet used to only a limited extent on railways of this class, and are almost invariably automatic, on account of the low cost. The Union system has semaphore signals operated by small secondary storage batteries in the base of the post; these are charged, through high resistance, by current from the third rail. In the Eureka system, the signals are lamps, and may be operated by a one-wire absolute block system or a two-wire permissive system. The latter gives greater flexibility, and by means of intermediate signals between turnouts it protects cars moving in the same direction and displays danger signals at the next turnout to prevent an opposing car from entering. In the United States system, there are two disks and lamps at each end of the block. An automatic switch on the trolley wire, 100 ft. before the signal, is operated by the trolley wheel of the approaching car. This causes a green disk and light to be displayed as the car enters the section, while a red disk and light are displayed at the other end. The green signal indicates a receding car, and the red signal an approaching car. This can be operated at speeds of 15 miles an hour. In the United system, the general arrangement is similar, but modified as follows: a red light indicates that an opposing car is in the section; a white light, that the section is clear; a green light, that a receding car is in the block, so that a second car may enter under control. In the General system, as employed on the Philadelphia & Western Ry., single-arm two-position semaphore home signals are used, standing normally at "proceed" and arranged with an overlap. Near Philadelphia the signals are about 3,300 ft. apart, and the overlap is an entire block. Farther

out the signals are about 1½ miles apart, and the overlap is 3,700 ft. These arrangements provide for a headway of two and five minutes respectively.

Cab Signals.—Several systems have been invented by which the signals are electrically indicated in the engine cab by small colored lamps. The object is to avoid the possibility of the engineman missing a signal accidentally or in a fog. They may be used either alone, or in conjunction with the ordinary signals. Some of these have been tried, but only to a very limited extent.

Automatic Stops.—To prevent accidents due to trains being accidentally or carelessly run past signals indicating "stop," various systems have been devised for automatically stopping the train, either by applying the brakes or closing the throttle. Track instruments operated from the signal mechanism engage with trips or electrical connections on the engine or motor car. These systems have been used to some extent on elevated and rapid-transit lines. The stop must be far enough ahead of the block signal to allow the latter to protect the train; or it must have an auxiliary automatic signal in the rear for this purpose.

Torpedoes or Fog Signals.—Another method to prevent accidents of the kind above mentioned is to use track instruments which place torpedoes on the track when the signal indicates "stop." These are specially adapted for locations where fog is encountered, and no special equipment is required on the engines. The proper system is to use torpedoes for both indications (one for "stop," two for "proceed"); otherwise a man might in a fog pass a signal at "clear" without seeing it and thus lose his bearings.

Derails.—At interlocking points derails are put in to derail a train passing a "stop" signal. Ordinarily these are switch points, often with a guard rail to keep the train from running off the roadbed. To avoid the objectionable breaking of the main track by these switches, Mr. E. C. Carter, Chief Engineer of the Chicago & Northwestern Ry., devised a derail which is a bar lying on the head of the track rail when the signal indicates "stop." The bar is 30 ins. long, 1¾ ins. thick, 2½ to 4 ins. wide. The wide end is inclined as a wedge to raise the wheel, which is then carried over the rail head and drops on the ties.

Miscellaneous.—Train-order signals are erected at stations to indicate whether a train must stop for orders. They are frequently targets mounted on the platform shelter or on a post in front of the station, but the semaphore type is preferable and is now very generally used. They are operated by levers at the operator's table or desk, and if used as block signals will be normally set at "stop." The signal should be a definite signal, and not merely a flag or lamp. It should give a positive indication for both "stop" and "proceed," but some of the targets are only visible when indicating "stop." The train-order signal affords no protection to trains, even at stations. Where block signals are not in use, it is important that trains should be protected while standing at stations. This may be effected by automatic signals, set at the proper distance. Grade crossings and the entrances to yards and passing sidings should also be equipped with signals to protect and facilitate traffic. All main-track switches should have distant signals (see Switches). At outlying sidings there may be automatic signals on the main track, or indicators to advise the signalman or station operator when a train is on the siding and clear of the main track; also a bell or signal at the switch to warn waiting trains when the main-track block section is occupied; this signal may also control a switch lock. At drawbridges, the signals on the approaches should be interlocked with the bridge locks and machinery. Thus when the bridge is to be opened, the towermen on the

approaches must first set the signals at danger, and then release the bridge locks. Till this is done the bridgeman cannot operate the bridge. When the bridge is again closed, the rail lifts and end locks must be returned to normal position before the approach signals can be lowered to allow a train to proceed. Isolated points requiring protection, such as bridges, tunnels, sharp curves, stations, etc., may be fitted with automatic signals forming a single block.

Interlocking.

The term interlocking properly includes the locking of the block instruments and apparatus of adjacent towers, but is commonly confined to the interlocking of switches and signals at junctions and crossings in such a way that they cannot be set for conflicting routes or to cause collisions. Thus in the case of a single-track Y-junction (A), where two lines (B–A) and (C–A) unite to form one line (A–D): If a train is running from (C) to (D) it cannot be given a clear signal for the junction until the signals have been set to stop trains approaching from (B) and (D) and the switches have been set for (C–A–D). Distant and home signals are used, and when the train has passed the former and entered the limits of interlocking, the signalman cannot move any signals or switches of this or conflicting routes until the train has passed beyond the limits. This locking of the home by the distant signal at "clear" should never be applied to block signals, as the signalman should have it in his power to stop a train at any time before it has actually reached the signal, in case of emergency. On the other hand, it should not be practicable to show a clear distant signal until the home signal is at "clear," and at interlocking plants it must be returned to "prepare to stop" before the home signal can indicate "stop." The interlocking should be so arranged that a home signal cannot be shown at "clear" until derails or diverging switches in conflicting routes are in their normal position and the switches for the required route are set and locked. The home signal when at "clear" should lock all switches and locks in the route as far as the point to which the signal gives permission to proceed, locking all opposing or conflicting signals and releasing the corresponding distant signal. Interlocking plants are not always used where the block system is in use. In such case the block signals protect against collisions on the open track, but safety against misplaced switches must depend upon the vigilance of switchmen and enginemen. Where interlocking plants are used in addition to the block system, they should be operated as an integral part of the latter. The interlocking plant is operated from the upper floor of a tower or cabin.

The switches and signals may be operated mechanically or electrically. With electric interlocking there is generally a generating plant in the tower, and each signal, switch, etc., has an individual motor, connected by wires with the apparatus in the tower or cabin. The movements are effected by push buttons or small levers. With this system distant signals may be placed 3,000 or 4,000 ft. from the tower, while with mechanical operation 2,000 ft. is about the limit. The locking is also electric, but electric locking may be applied to mechanical interlocking plants. The locking includes both the mechanism in the tower and at the different outdoor points. The former is so arranged that the movement of levers for a certain series of operations locks the levers which would be used in a conflicting series. At the same time the switches, etc., are locked in the position at which they are set. The signals governing these

switches cannot indicate "proceed" until this locking is effected and must be returned to the "stop" position before the switches can be unlocked.

In mechanical interlocking, the movements are effected by means of L or inverted T levers, the upright end working between sector guides in the floor. A latch handle against the lever handle operates a stop fitting in notches at each end of the sector. The locking mechanism is connected with this latch, so that when the lever is locked the latch handle cannot be moved to raise the stop, and consequently an attempt to pull a locked lever does not put any strain on the wire or rod connections. To the ends of the horizontal arms of the lever are attached wires, chains or rods which run down to the lower floor of the tower and out to the roadbed. This forms the lead-out.

Lines of 1-in. pipe are generally used for operating switches, detector bars, locks, derails (and stop blocks), and home signals. Other signals may be operated by wire, but in many cases they are all operated by pipe lines, which insure a positive and uniform movement. Distant signals, however, must generally be connected by wire, as 1,000 ft. is about the limit for their practical operation by pipe lines. Very long pipe lines are liable to buckle, and are hard to operate if connected to anything but signals at distances over 800 ft. Wire-connected signals are operated at distances of 2,000 to 4,000 ft., but are apt to be unsatisfactory, due to the arm not having a uniform movement; 2,000 ft. is about the limit for reliable service. Electric connections may be economical and necessary for distances of over 1,200 ft. for pipe or 2,000 ft. with wire. Pipe lines have compensators to provide for expansion and contraction due to changes in temperature; there is usually one in each line 50 to 800 ft. long, and two in lines up to 1,200 ft. They are usually of the "lazy-jack" or double bell-crank pattern. The pipes are supported at intervals of about 7 ft. on roller carriers, while wires are supported on small pulleys attached to stakes. The wires may be carried under streets, etc., in $\frac{1}{2}$-in. or 1-in. pipes filled with crude oil, the pipes requiring to be refilled about twice a year. The foundations for pipe carriers, bell cranks, chain wheels, etc., should be of concrete, though wood is frequently used.

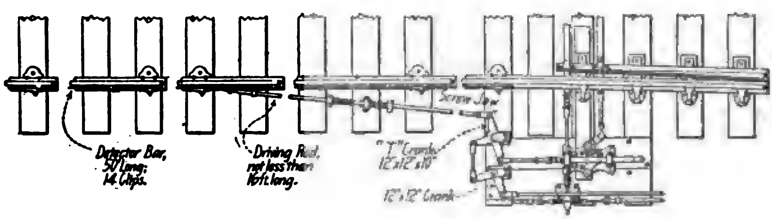


Fig. 191.—Bolt Lock for Switch.

In mechanical interlocking, switches are usually locked by bolt locks, a typical arrangement of which is shown in Fig. 191. The head rod of the switch, or a rod extending from it beyond the rails, has two holes, engaging with a horizontal bolt or plunger moving parallel with the rail in a casting on the tie. When the switch is properly set in either position, the bolt is thrown and enters the hole; the movement of its operating rod unlocks the lever of the signal governing the switch. If the switch is not properly set, the bolt cannot enter and consequently the signal remains locked at "stop." When the switch is locked, the bolt cannot be withdrawn while a train is passing, a detector bar

preventing the movement of the operating rod. The bar is at least 50 ft. long. so that one wheel of a train will always be over it. It is hinged on studs, and lies against the outside rail head. In moving it has a longitudinal motion, and rises slightly above the rail head, which it cannot do as long as a wheel is on the rail. These bars are very extensively used in interlocking work, but track circuits may serve the same purpose.

Where the tower is not part of a block system, track instruments may be set at a suitable distance and connected to a bell or indicator in the tower. The towerman is thus notified that a train is approaching, and on what track. Without such apparatus he must rely on the engine whistle. If he fails to hear this or to comprehend at once on which track the train is approaching, he may fail to set the signals promptly, and thus check a fast or heavy train. At crossings with light and slow traffic, distant signals may sometimes be omitted, fixed "slow" signs warning all trains to approach the crossing slowly. Interlocking plants are being used to protect the increasing number of crossings of electric railways with steam railways; these plants are practically identical with those used at the crossings of steam railways.

CHAPTER 16.—ELECTRIC RAILWAYS.

The great development of electric traction, not only for city and suburban service, but also for long-distance interurban and rural service, has been attended by very considerable improvements in track construction, and has opened a new field for engineers in the construction and maintenance of these lines. On lines outside of city and suburban streets, and built at the sides of roads or on their own right of way, the construction is usually very similar to that of an ordinary railway. If the line follows a highway it may be paved over like the rest of the road. In city streets the track construction is usually of a special character, adapted to the style of paving. Greater permanence of surface is required here, as the track must maintain its conformity to the surface of the street, and there is no opportunity for the continual tamping, surfacing and tightening of bolts which is done on railway track. For this reason a substantial and permanent foundation is a necessity.

For street railways, the excavation should be carried below the level of the bottom of the ties. The subgrade should be rolled, and then covered with concrete; or with a bed of slag, broken stone, or gravel, well rolled to a finished depth of 8 to 12 ins. below the ties. The same material should be filled in between the ties and form the foundation for the paving. In city streets with heavy traffic, a concrete foundation for the tracks and paving is desirable, and with such construction the use of wooden ties may be dispensed with, the rails being laid directly upon or embedded in the concrete. Both systems are in use, but the tendency is to eliminate all wood in heavy first-class construction, the rails being connected at intervals by tie-rods or tie-bars through the webs. It has been contended that tracks having rails laid upon the concrete would be very rough riding and cause increased wear of wheels, bearings and cars, but experience does not sustain this objection, especially where deep and stiff girder rails are used, and where the track is rigidly anchored to the foundation. In

fact, some of the most easy riding track is built in this manner, and on two parts of a line where the concrete base and the wooden cross-tie system were both in use, no difference in the wear of rails or equipment was found after careful investigation. Where a well-built track proves to be hard riding, attention may be directed to the car springs, as these have an important influence upon this matter as well as upon the wear of rails, and in many cases too little attention is paid to the design of the springs and spring rigging.

The rails are almost universally of the girder or ordinary T sections, the various forms of strap, box and compound rails and shallow rails supported on chairs being practically obsolete. The deep rails are rigid, and if well anchored are free from the wave motion which proves destructive to paving. Girder rails are used for lines of all classes, but more especially for city streets; T rails are also used in streets, but mainly for suburban and country lines. The rails used in street tracks are of the types shown in Fig. 192: 1, Grooved girder rails; 2, Side-bearing girder rails; 3, Tee-girder rails; 4, Ordinary tee rails. The grooved rail has the head flush with the paving, a groove forming the flangeway for the wheels. In one type the guard side of the groove is about ¼-in. lower than the running head of the rail. For city streets the grooved head is the best, the rail head being wide enough for the widest wagon wheels and having a groove for the car-wheel flanges. These grooves form the only break

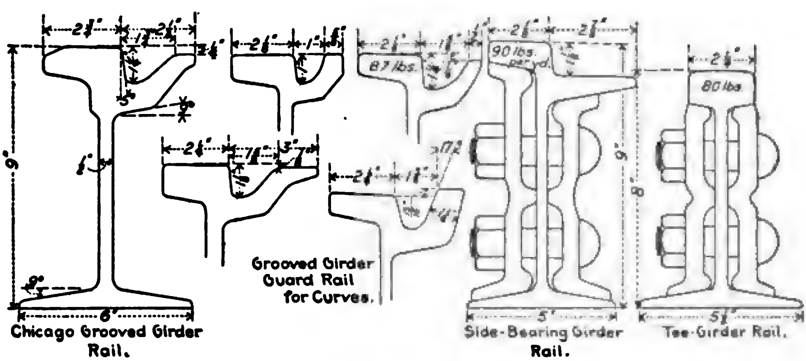


FIG. 192.—Rails for Street-Railway Track.

in the street surface. The rail is of little advantage in ill-paved rough streets. The inner side of the groove is nearly vertical, but the outer side may be flaring or vertical. The latter gives the least break in the pavement, but the former enables narrow wheels to turn out easily and is also more easily kept clean. Dirt and snow in the groove offer some additional resistance to traction, but the general advantages of this form of rail far outweigh any minor objections on the part of the railway companies. When first introduced, following long-established English practice, it was claimed that narrow tires would be caught and that the grooves would be so clogged up with street dirt that cars would not be able to run. Practical experience has shown that the use of these rails is practicable and advantageous. With the side-bearing rail there is no groove proper, but the paving between the rails of each track is lower than that of the rest of the street. This makes an irregular surface, inconvenient for driving and difficult to keep clean. Girder rails are 6 to 10½ ins. high, and

weigh from 70 to 140 lbs. per yd. The use of T-girder rails, or T rails of greater height than those used on steam railways, has become very general for city and suburban lines. Ordinary T rails are also frequently used, but the lighter sections are too shallow for use with brick or block paving, as there is not room for the proper cushion course of sand over the rail flange. The T rail, whether of ordinary or girder pattern, is prohibited in some cities.

The rail joints may be spliced in the same way as those of steam railways, but for very tall rails the splice bars are usually of channel section, with a double row of bolts, and have sometimes a horizontal rib which bears against the web of the rail, as shown in Fig. 192. Many of the special joints described in a former chapter have also been adapted to street-railway track. Reinforced joints, having base pieces riveted or bolted beneath them, have been used in many cases. With 5-in. and 6-in. rails at Scranton, Pa., ordinary angle bars are bolted to the rails with six bolts, and an inverted piece of rail 4 ft. long is riveted to the base of the rails with 18 rivets; four of these are of copper to act as electric bonds. A pneumatic riveter is used, suspended from a derrick on a construction car. As the work on rail joints represents some 75% of the general track maintenance, and as this work is done under unfavorable conditions, the desirability of eliminating joints may readily be seen. For this reason 60-ft. rails are very commonly used. As the rails are used to carry the return current, the joints must be bonded or connected by copper wires or plates, so that the current will flow uninterruptedly from rail to rail and not seek an easier path through the earth owing to the resistance which it encounters in passing the joints. This bonding is often defective or of insufficient capacity, the conductivity of the bonds being far less than that of the rails. As a result the current escapes and travels along water and gas pipes and other conductors offering less resistance. This causes electrolytic corrosion or electrolysis.

Within recent years the elimination of the joints by welding the rails together has been very extensively practised, and in general with good results. As the rails are embedded in the paving, and only the top of the head is exposed, the contraction and expansion due to temperature are very much reduced, and where breaks occur they are more often due to faulty welding than to the contraction of the rails. It is claimed that welded joints eliminate the necessity of electric bonding, but it requires careful work to make welded joints which are equal to the rail in conductivity. At Milwaukee, the cast-welded joints show a conductivity of 100 to 140% as compared with the rail itself; any joint showing less than 80% is broken and remade. The joints may be welded electrically or by pouring melted iron around the rail ends. In electric welding, steel bars about $1 \times 3 \times 15$ ins. are clamped to the rail webs, and three electric welds are made at the rail ends and the ends of the bars, heavy pressure being applied while the rails are heated by an electric current. In the "cast-weld" system a hinged mold is clamped to the joint, and a vertical screw applies pressure from above to keep the rail ends from buckling vertically under the influence of the heat. Metal heated to a white heat in a portable cupola is then poured into the mold, which is left for about an hour. The metal is usually composed of about 67% pig iron and 33% scrap, and the best results are obtained where a thin iron shim or plate is inserted at the joint. In "thermit" welding a self-fusing metal is put in the mold and ignited. The rail ends must be clean and bright to insure good work, and the finished joint should be ground or dressed to a plane surface. Breaks are classed as broken rails, broken joints

and slipped joints, the latter being due to imperfect welding. They may be repaired by rewelding, putting on splice bars, or by cutting out 10 ft. of rail and putting in a new piece with two joints.

The rails may be laid (with or without ties) upon a continuous sheet of concrete which also supports the paving, or upon concrete stringers. In the former case, where concrete forms a foundation for both the track and the paving, the depth may be increased at the track: 1, Under the entire width of track, if ties are used with ordinary spacing; 2, Under the ties only, where these are 8 to 12 ft. apart; 3, Under each rail, if ties are not used. Concrete stringers are adapted to streets having no concrete foundation, or old concrete of insufficient thickness to carry the track. At Tacoma, Wash., 7-in. 70-lb. T rails are laid on stringers 10×14 ins.; no ties are used, but the rails are connected by tie-rods. In the stringer system, a trench is dug for each line of rails, about 20 ins. wide at top and 16 ins. at the bottom, which is 8 to 10 ins. below the rail base. Wooden blocks are placed in the trenches, 10 ft. apart, the rails being spiked to the blocks and spliced. When the track is adjusted to line, gage and surface, the trenches are filled with concrete, tamped well under the rails to give them a full bearing, and allowed to set for about six days, according to the weather. On existing lines, sections of about 1,000 ft. of one track may be given up, portable crossovers connecting the tracks at the ends of each section, or a temporary track being laid on the street if conditions permit.

Wooden ties are usually of sawed pine, oak, cedar or chestnut, 6×8 ins. and 7 to 8½ ft. long; a few roads use 6-ft. ties, which are not to be recommended. They are spaced 18 to 30 ins. c. to c., except that where they are used mainly to hold the rails during construction, they may be 5 to 12 ft. apart. Ties embedded in concrete do not show such rapid decay as might be expected. Ordinary or screw spikes are used. Steel tie-plates are generally placed on all ties, combination tie-plates and braces being used on all or a certain proportion of the ties. Steel ties of I-beams, troughs or angles are sometimes used, being embedded in concrete; the first are by far the most general. They may be spaced 5 to 10 ft. apart. High rails are very frequently connected at intervals of about 10 ft. by 1-in. tie-rods (if to be embedded in concrete) or flat tie-bars (if to fit between rows of paving blocks). These have threaded ends which pass through the webs of the rails and have nuts on both sides of the webs. The rods and rail braces are to maintain the gage and resist lateral thrust.

The switches in paved streets are usually of the tongue pattern, a pivoted tapering tongue moving in a casting having a wide groove. The switch or tongue is placed on one side of the track only, with a fixed point or "mate," like a long frog point, on the opposite side. Frogs and crossings are usually steel castings, manganese steel and other specially hard steel being often inserted at the points of most severe wear. Passing sidings may be arranged in different ways: (1) The main track continued in a straight line, with the siding on one side; (2) Both tracks diverted equally from the center line; (3) The main track offset so as to overlap for the length of the siding. In the third case, automatic spring switches are set normally for the straight line; cars in each direction have a facing switch always open, and trail through a closed switch at the leaving end. Junctions and intersections in cities often require complicated special work, which is laid out with great accuracy.

The gage of street-railway tracks is usually 4 ft. 8½ ins., with tracks spaced 9 ft. to 10 ft. c. to c. Gages of 3½ ft. to 5½ ft. are used in some cases. On

electric railways, grades of 5 to 6% are frequent, and 8 to 12% grades are successfully operated. On cable lines (now almost obsolete), grades of 15 and 18% are surmounted. Very heavy grades on electric city lines (15 to 18%) are occasionally equipped with a counterweight system. A counterweighted truck on a cable running in a conduit travels up the grade as a car descends, the car being controlled by a special cable grip car which runs on the incline. Curves may be as sharp as 30 to 125 ft. radius. Transition or spiral curves are frequently adopted, not only for ordinary curves on outlying parts of the line where cars run at high rates of speed, but also on sharp city curves, to eliminate the severe shock and swing caused by a car passing from the tangent to the curve. In one case, curves of 400 ft. radius have transition curves 60 ft. long, with an initial radius of 3,400 ft.; 33-ft. curves have transition curves running out to 180 and 368 ft. at the ends. Terminal loops of 33 ft. radius have the gage widened ½-in., but no elevation is required, as the speed is invariably slow. On curves up to 100 ft. radius, the gage may be widened ¼-in., but beyond that the standard gage is commonly used. Curves of 250 and 300 ft. radius on high-speed suburban lines are sometimes elevated 3½ to 4 ins., using a guard rail on the inside. In city streets an elevation of 2 ins. can sometimes be obtained on sharp curves without undue interference with the paving, but curves at intersections can have little or no elevation. In Boston the rail is elevated for a speed of 15 miles per hour, where the street construction will permit of using this formula: $E = (GV^2) \div (32.2R)$.

It must be borne in mind that the width of tread of wheels for electric cars is usually less than that of ordinary railway wheels, so that widening of gage may unduly reduce the bearing of the wheel upon the inner rail. On sharp curves where guard rails are required (sometimes all under 500 ft. radius), the gage may be widened a sufficient amount (according to the width of the groove) to prevent the flange of the wheel from cutting into the tread of the outer rail. Guard rails are required on sharp curves, and these may be grooved girder rails with wide grooves and guards of exceptional thickness. With T rails, an inside guard rail of the same section (or a heavy rectangular bar) may be bolted to the web of the track rail, spacing blocks of the required width being used. Special care must be taken in laying out curves to insure easy riding and (on double track) to prevent any liability of cars striking when passing on a curve. On very sharp curves it is impossible to spread the curves to prevent this interference with long cars, and cars must not attempt to pass each other. There is a movement towards standardizing wheels, and on interurban railways the wheels conform largely to the standards of the Master Car Builders' Association, already described. Street-car wheels have treads 2¼ to 2¾ ins. wide; flanges ⅝ to ⅞-in. deep, and 1 to 1¼ ins. thick. Where interurban cars are run over city tracks, all grooves must, of course, be designed for the larger flanges. On double-track lines in streets the outer rails may have to be ¼-in. or ½-in. lower than the inner rails, to conform to the crowning of the surface.

In paved streets the same paving material should be used for the entire width of the street, so as to distribute the traffic, but many cities allow the use of an inferior material between the rails and tracks. The track in city streets should be considered as a part of the street construction. Under an advanced system of municipal administration it should be designed, built and maintained by the city, or at least under its direct control. Several cities already exercise more or less control over the construction, but municipal authorities might well

undertake closer control of track construction and maintenance. Various styles of paving are adopted to conform to the design of track. Concrete may be filled between the ties to form a foundation for brick or stone paving, or it may be laid over the ties to the necessary height for an asphalt paving. Where asphalt is used, or where a macadam road has heavy traffic, a line of bricks or granite blocks may be placed to form or protect the grooves for the wheel flanges. On heavy grades a similar plan may be used to prevent macadam paving from being washed out along the rails, one or two lines of brick being laid outside of the rail head. Asphalt usually deteriorates if laid against the rails. A macadamized street, having tracks laid with 85-lb. 5½-in. T rails, has broken stone 5 ins. deep under the ties, and filled in to 3 ins. below the top of the rail; the top course is of gravel and stone screenings. With T rails in brick paving there are numerous methods of construction, and six methods of forming the flangeway groove are shown in Fig. 193.

In the reconstruction of the Chicago street railways (1907), 9-in. 129-lb. 60-ft. grooved girder rails are used, laid on Carnegie I-beam steel ties or wooden ties 5 ft. c. to c. They are laid with square joints, spliced with very short bars having only one bolt to each rail; the bolts are at the bottom of the web. They are fastened to the wooden ties by screw spikes, and to the steel ties by hook-

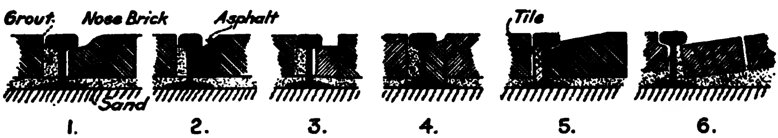


Fig. 193.—Methods of Forming Flangeway for Tracks in Streets with Brick Paving.

headed wedges or keys. Steel tie-plates are used in both cases, and the rails are connected at intervals by tie-bars. Concrete is filled in beneath and around the rails (but kept clear of the joint bolts); upon this is a sand cushion for the granite paving blocks, which are set ⅛-in. above the guard (and ⅛-in. below the head of the rail). On minor streets, wooden ties are laid 24 ins. c. to c. on an 8-in. bed of broken stone which has been well rolled. Concrete is filled in as above. In this work electric power from the trolley wire was used to operate concrete-mixing machines, augers for boring the ties, and spike-setters for driving the screw spikes.

At Indianapolis, the standard track construction is on the combination tie and beam system, Fig. 194. The concrete stringer is 10 ins. deep under the rail; it has either an 18-in. flat bottom and sloping sides, or is of curved section. The ties are 6×8 ins., 8 ft. long, 10 or 12 ft. c. to c., the concrete being 6 ins. deeper for a width of 24 ins. under each tie. Each rail has a brace tie-plate on every tie, and two between the ties, the latter having anchor bolts embedded in the concrete, so as to hold them rigidly upon the concrete. A 7-in. 91-lb. T-girder rail is used. When the cross-tie system is employed, the rails rest on white-oak ties 24 ins. apart, with a brace tie-plate on every third tie. Under the ties is a 6-in. bed of gravel concrete, which is also filled in between and over them. The use of ordinary concrete under the ties necessitates the stopping of traffic (as the track cannot be held to line on wet concrete), and where it is not practicable to divert traffic a dry concrete is used. The gravel and sand

are excavated with a ½-yd. orange-peel bucket; two sacks of cement are thrown upon it, and the load is then dropped into a concrete mixer, which delivers it directly to the ballast cars. This concrete has the ordinary moisture of the pit gravel. It is laid in the same way as gravel ballast, and the track properly

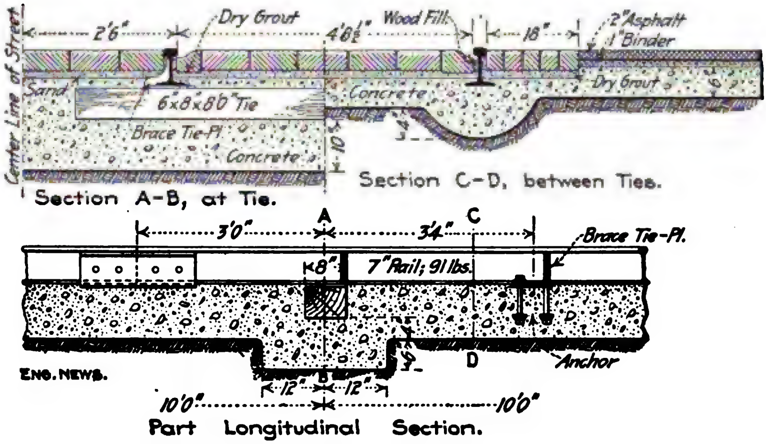


Fig. 194.—Street-Railway Track; Indianapolis, Ind.

lined and tamped to the permanent grade. After several months the absorption of moisture from the earth is sufficient to allow the concrete to set to a strength approximately 80% of that of similar concrete mixed with water in the usual way. At the end of three years it seems to be practically as strong as ordinary concrete, and the track has maintained its line and grade.

At Kansas City, Fig. 195, the ties are laid on 6 ins. of stone ballast, which is also filled 2 ins. between them. On this is the concrete foundation for the paving. The business streets have 141-lb. grooved-girder rails, but other

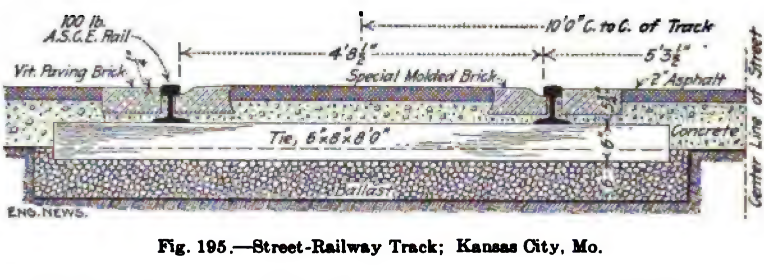


Fig. 195.—Street-Railway Track; Kansas City, Mo.

streets have T rails of the 100-lb. section of the American Society of Civil Engineers. With asphalt paving, a line of brick is laid on each side of the rail. At Toronto, a 6-in. bed of concrete is put in for the entire width of the street, increased to 12 ins. for a width of 20 ins. under each rail. Under the tracks the concrete is first laid to within 4¼ ins. of the rail; wooden blocks are set on this to carry the rails, and the concrete is filled in to 1¾ ins. above the base of rail. On this is a 1-in. sand cushion and a 4½-in. brick pavement.

A T rail or a 7-in. grooved girder rail is used, according to location; in the former case a row of nose blocks of scoria (or slag) is laid inside each rail to form the groove. The rails are 60 ft. long, with 24-in. Continuous and Atlas splice bars. They are bolted to ties of old 4½-in. T rails (inverted) 12 ft. apart, and are also connected by ⅞-in. rods 6 ft. apart. At Milwaukee a 7-in. 95-lb. T-girder rail is used, having a head 3 ins. wide. The rails are in 60-ft. lengths, with cast-welded joints. They are laid on cedar ties 24 ins. c. to c., with 6 or 8 ins. of concrete (1:2½:5) beneath them. The subgrade is flooded and tamped, or rolled, and the concrete allowed to set for a week before cars are run. The stone blocks are laid as at No. 6 in Fig. 193.

The poles for the trolley wires are usually about 30 ft. long; 40 to 50 ft. at crossings and if carrying transmission lines. They are set 6 or 8 ft. in the ground, and are vertical if single poles carry brackets for the trolley wire. If this wire is supported by transverse span wires between pairs of poles, these are inclined outward 4 or 5 ft. in their height. They are generally 100 ft. apart. Wooden poles are about 5 to 7 ins. diameter at the top and 10 to 13 ins. at the butt. They may be of cedar if left round, or chestnut if trimmed to a square or hexagonal section. Very frequently they are tarred to the ground line and painted above this. Creosoted poles are durable, but are good conductors. Iron poles may be tubular or built-up, the former being the most common and usually consisting of three tubes, 5, 6, and 7 ins. diameter, with telescoped and swaged joints. Concrete poles have been used in several cases. Those of the Fort Wayne & Wabash Valley Ry. are 1:3:3 stone or gravel concrete, having a 1:3 facing mixture. They are 32 ft. long, 8 ft. in the ground, 10×10 ins. to 6×6 ins. section, and weigh 3,300 lbs. each.

Interurban lines are as a rule operated on the overhead trolley-wire system. The wire is about 22 ft. above the rails, and is carried by bracket arms on a single line of poles set beside or between the tracks, or by transverse span wires between poles set on both sides of the track. Side poles are 7 or 7½ ft. from center of track, and double poles 15 or 16 ft. apart. The poles may be erected by ropes and pike-poles, or by means of a derrick-wagon Cables are hauled over the cross-arms by a rope and team. The trolley wire may be put up by a tower car, in front of which is a truck with the spool of wire. The wire has a distinct sag between the poles, but for high speed a level wire is desirable. This is secured by supporting it at intervals by hangers from one or two longitudinal catenary cables carried by brackets or by bridges spanning the track. On the Indianapolis & Cincinnati Ry., where speeds of 65 miles per hour are attained, there is a single catenary cable on brackets carried by poles 120 ft. apart (50 ft. on sharp curves), and 7 ft. from the center of the track. The hangers are 10 ft. apart, and the trolley wire is 18 ft. above the rails. For some lines with high speed and heavy traffic, the third-rail system is used, in which a shoe on the car truck rides upon a conductor rail laid at the side of the track. This may be a T rail, with the shoe riding on the top, or a double-headed rail carried by overhanging brackets so that the shoe rides against the bottom face. The wearing face is usually 2½ to 3½ ins. above and 27 to 32 ins. from the track rail. With the under-running arrangement, the rail is easily protected from snow and against accidental contact with persons.

Many interurban lines are built on their own right of way. In such cases the ordinary system of track construction may be followed, using 60-lb. to 80-lb. rails spiked to ties 18 to 30 ins. c. to c., laid on a suitable amount of ballast.

Where the line is laid along a road, however, T rails or girder rails are generally used, being connected by tie-rods about 10 ft. apart. They are generally single track, with passing places at intervals, sometimes every two miles. A No. 6 spring-rail frog is sometimes used for the turnouts, as this gives a theoretical lead of 56.52 ft., which is convenient for placing the turnout within the 100 ft. spacing of the trolley poles. Many roads use rails 60 ft. long; in some cases they are satisfactory, but in others it is difficult to keep the rails in line. In unloading them, two dollies of different heights are set beyond the rail car, each with a roller on top. The bond holes are sometimes drilled by machines mounted on a car, the drills and propelling machinery being operated from a gasoline engine. The Milwaukee interurban lines have 66-ft., 80-lb. rails, with square joints (except on curves). They are spliced with Weber joints and anchored at intervals of 200 ft. to prevent creeping. The open track has cedar ties spaced 16 ins. apart in the clear, without regard to width; hewed oak ties are used on curves, and sawed oak ties on sidings.

Roads of this class should have ample signal and safety equipment, as there is apt to be more liability of accidents than on steam railways. The methods of operation are often unsystematic, the discipline slack, and the rules not rigidly enforced. The schedules are also variable. Train dispatching by telephone orders is the usual system of operation, but the block system is sometimes established. (See Signaling.) Road crossings should be equipped with automatic electric-bell or lamp signals, as the cars run swiftly and quietly and the motormen very generally fail to sound their whistles. Grade crossings of electric lines with steam railways are too numerous, and could often be avoided. They should be efficiently protected, as noted in a previous chapter. The grades and curves may be considerably heavier than on ordinary railways, but it seems probable that the curvature is in many cases too sharp for safe and efficient operation at high speeds, especially as cars are run at 50 to 70 miles per hour on many of such lines. Curves of 14° to 20° are sometimes necessitated by the fact that the location has to be made to fit a right of way already purchased. The rules used by steam railways for superelevation of curves are not satisfactory for electric railways, owing to the lighter weight of the cars, the arrangement of the motive power, and other conditions.

The Aurora, Elgin & Chicago Electric Ry. is a high-speed electric interurban line, operated on the third-rail system. Its right of way is mainly 66 ft. and 100 ft. wide, all fenced, and on single track all cuts are excavated for a double-track roadbed. The ordinary curves are of 1° to 4°, with 16° curves at cemetery property which could not be purchased. The superelevation on curves was originally 1 in. per degree, with a maximum of 5 ins., but for high-speed service it has been found necessary to give 3 ins. elevation on 1° and 2° curves. The elevation is run out 1 in. in 50 ft. and the ends of the curves are spiraled. The width of roadbed is 16 ft. for single and 28 ft. for double track (13 and 26 ft. over ballast). The double tracks are 13 ft. c. to c., with crossovers 4 miles apart. On single track there are passing sidings 4 miles apart, and long sidings at curves to insure safety in high-speed service. The sidings are from 700 ft. to a mile in length. The 80-lb., 60-ft. rails of the Am. Soc. C. E. section are laid with broken suspended joints, spliced with 28-in. angle bars and four 1-in. bolts. There are 32 oak or cedar ties to a rail length, with from 6 to 9 ins. of gravel ballast under the ties. The joints are bonded, and the rails cross-bonded every 500 ft. The main-track turnouts have split

switches with 15-ft. reinforced switch rails and No. 10 spring-rail frogs. The conductor or third rail is of the 100-lb. Am. Soc. C. E. section, in 33-ft. lengths. To give great conductivity it is of 0.1% carbon, but as the soft steel rusts and corrodes more rapidly, it was painted with a cheap asphalt paint thinned with gasoline. This soon wore off and the rail became rusty. It would be better to use a good quality of durable protective paint to keep the rail in condition and to reduce the labor cost for cleaning and repainting.

The holes for the bonds were formed in the rail flanges after the rails were laid; some were formed by a portable hydraulic press, and others drilled by hand or by a gasoline machine on a car. Every fifth tie is a 6×8-in. white-oak sawed tie 9 ft. long, the end carrying an insulating support for the third rail. The head of this rail is 11$\frac{3}{16}$ ins. above the tie and 19½ ins. from the gage side of the track rail. At grade crossings the third rail is cut, the last rail being dropped 2 ins. in its length and fitted with a 24-in. incline to catch the shoe on the car. The current is carried across by a cable laid under the road. This is protected by being laid in a 3-in. bituminized fiber conduit, covered with 3 ins. of gravel concrete. Signs, cattleguards and warnings as to the third rail are placed at crossings. The cars used are 53 ft. long, weighing about 40 tons empty; they are geared for speeds of 73 miles per hour, and the acceleration is two miles per second, or 60 miles per hour in 30 seconds. In track work 60-ft. rails are more difficult to handle and much more difficult to keep in line than 30-ft. rails. There is practically no difference as to keeping the rails in surface; any difference is in favor of the 60-ft. rail. As the third rail interferes with the lining of track on that side, a chain is used with a hook at one end and a ring on the other. The hook is slipped over the rail base and the chain passes under the third rail, so that the men on the outer side of that rail can put their lining bars through the ring.

Organization.—The organization of the maintenance-of-way department of the Philadelphia Rapid Transit Co. is as follows: The system (with about 619 miles of track) is under the charge of an engineer of way and is divided into seven divisions. The five main divisions average 109 miles each. In the other two divisions one man has charge of approximately 40 miles of track, chiefly suburban, and the other of about 25 miles. The work in each of the divisions is in direct charge of a superintendent, who looks after track, paving, bridges and building repairs. The work in general is outlined each month by the engineer and supplemented by written orders daily. In addition to these divisions there is a floating gang which has charge of the building of new electrical conduits, bonding track, and miscellaneous repairs to pavements and masonry work. Such work as cleaning and oiling curves and switches, and sanding track, is done by men specially detailed for that purpose in each division. All jobs have a number, and sheets from each division showing the distribution of time and labor are forwarded daily to the main office. From these sheets is compiled a monthly report to the president and general manager. On the Chicago City Ry., the maintenance of tracks is divided among four general foremen, who report to the superintendent of tracks, and the work is divided among them according to character rather than location. One man is in charge of straight track maintenance of the entire system, having foremen under him responsible for different sections. Another has charge of special track work. A third maintains railway crossings, track elevations and car houses. The fourth has charge of handling all material, including teaming and supply-car

service. For emergency work, such as wrecks, snow, etc., the regular force is divided into sections, with separate divisions alloted to each general foreman. The Aurora, Elgin & Chicago Ry. has two roadmasters: one for the third-rail system, with about 87 miles of track; the other for the interurban and city trolley lines, with about 75 miles. On the third-rail system, the sections have an equivalent of 8 miles of single track, and each foreman has five men as a regular gang. Trackwalkers are employed on many interurban lines.

PART II. TRACK WORK.

CHAPTER 17.—ORGANIZATION OF THE MAINTENANCE-OF-WAY DEPARTMENT.

In the organization of railway service there are two distinct systems: (1) The Division System. Each division is operated practically as an independent line, its superintendent having control of transportation, maintenance-of-way, and maintenance of equipment. All other officers on the division report to him, and he reports to the heads of the several branches of the service. The latter transmit all instructions to him, which he refers to the proper subordinate officers. (2) The Department System. The several branches of the service (for the line as a whole) are centered in the heads of certain departments, which are usually as follows: (A) The engineering department, in charge of the construction and maintenance of line, roadway and appurtenances; (B) The mechanical department, in charge of locomotives, cars, machinery, floating plant, shops, etc.; (C) The operating department, in charge of train service and traffic. In this system the division engineers report to the chief engineer, the division master-mechanics to the superintendent of motive power, and the division superintendents to the general superintendent. The first system is in many ways the better, as all authority and responsibility for the work of each division are concentrated, which conduces to the economy and efficiency of the service. The maintenance-of-way forces may be organized in different relations to the general organization: 1, As a separate department; 2, As a division of the engineering department; 3, As a division of the operating dapartment. The first is practicable only on very large railway systems, and of the two others, the former is the more appropriate and advantageous.

On a large railway having the maintenance-of-way work under the engineering department, it would be impossible for the chief engineer to attend personally to details of track work, as well as to all the other varied work of his department. There is consequently a growing tendency to make this a separate branch, in charge of an engineer of maintenance-of-way. He may report to the chief engineer or to the head of the operating department, according to the system of organization. In very many cases the roadmasters report directly to engineers and are under their direction. In some cases there is a general roadmaster over the division roadmasters, but this practice is not general. In other cases there is a superintendent (or inspector or engineer) of track, reporting directly to the general manager. There is no uniformity in titles or in details of organization; these vary arbitrarily and also with the mileage and traffic of the several roads. Some small roads have engineers,

while other considerably larger roads have no track or engineering official above the rank of roadmaster. On small roads where all departments of service are centered in one officer, there is danger that track maintenance work will be overlooked in consequence of the daily pressure of work relating to the traffic and general business. Several railways of the smaller class have therefore a special officer in charge of maintenance-of-way. The bridge and signal forces should be organized as divisions of the engineering or the maintenance department. Details of the systems of organization on a number of railways are given at the end of the chapter.

Organization for Track Work.

Whatever may be the system of organization of the maintenance-of-way department, the system of organization of the working forces is practically uniform. The line is divided into sections, the work on each of which is in charge of a section foreman and laborers constituting the section gang. The length of section varies according to the number of tracks, character of construction, number of frogs and switches, and the amount of traffic. The average is about 5 to 7 miles on single track, and 3 to 4 miles on double track. On four-track lines the length of sections is from 2 to 3 miles. The amount of work does not increase directly in proportion to the number of tracks. Thus ditching, clearing right of way, cutting grass, etc., average about the same in any case, the greater amount of clearing on a single-track right-of-way compensating for the greater care usually required on double track. On double track, however, the men know in which direction to look for trains, and can therefore do their work to better advantage and with greater safety.

The distribution of track forces on several railways is shown in Table No. 18. On the Lake Shore & Michigan Southern Ry., the length of the roadmasters' divisions varies from 83 miles for a busy main-track division (sometimes with four main tracks) to 170 miles for branch divisions with light traffic. The length of single-track sections varies from 3½ to 7 miles for about the same reasons. The double-track sections vary from 3½ to 4 miles; three-track sections, about 3 miles; and four-track sections, about 2½ miles. The track forces in winter are reduced to about 1 man to 2 miles on branch sections and 1 man to 1½ miles on main-track sections. The summer force varies from 1 man to 1½ miles on thin branch sections, to a sufficient number to get the work done on the busy main-track sections. The Chicago, Milwaukee & St. Paul Ry. has some branch lines on which no regular laborers are employed during the winter. Only the foremen are retained, and they employ men as required for clearing snow and other work. On the New York Central Ry., the length of roadmasters' divisions ranges from 84 to 150 miles on single track, and from 30 to 60 miles with four tracks. The lower limits of four-track subdivisions also have 45 miles of double track in addition. Floating gangs are used for ballasting, laying new rails, and for construction work. A floating gang usually consists of a foreman, an assistant foreman, and 15 to 50 men. When there are more than 30 men, there is also a timekeeper. At the end of the table are included some railways of the smaller class.

While the organization is almost invariably as above described, a special system was introduced successfully on the Ohio River Ry. by Mr. C. E. Bryan. This provided for permanent floating gangs, leaving only the lighter class of work to the regular section gangs. The divisions were subdivided into 30-mile

lengths, each of which had a floating gang consisting of a foreman, 20 men, and a cook, and was provided with a boarding train. These were under the direction of the roadmaster of the division. The sections were changed from 7 to 8 miles, with gangs of 4 men instead of 7 (including the foreman). These gangs went over their sections daily (the trackwalker being dispensed with); they inspected the track, made light repairs, fixed fences, kept station grounds neat, etc. This had the advantage that the inspection was done under the eye of the foreman, and repairs could be made at once. The floating gangs did all such work as ballasting, renewing ties and rails, widening banks, ditching, etc. Under this system, the work of renewing rails, ballast and ties was carried on in 1900 without any increase in forces such as would have been required under the ordinary system. Each division was able to do all this work on about 8 to 10 miles per month.

TABLE NO. 18.—ORGANIZATION FOR MAINTENANCE-OF-WAY.

Railway.	Length of Roadmasters' Divisions.	Length of Track Sections.	No. of Men in Section Gang.	
			Spring.	Winter.
	miles.	miles.		
Atch., Top. & S. Fé.	140 to 150	8, Sin. track	5 to 7*	3*
Balt. & Ohio.	40 to 100	6 to 8, Sin. track	.....	...
" " "	....	4 to 5, Dbl. track	.....	...
Boston & Maine.	About 115 of d.-t. main line & 115 of s.-t. branches	4 to 5, Sin. track	5	3
" " "		3, Dbl. track	6 to 9	3
Chicago & Northwestern.	150 to 200, s. t.	5 to 6, Sin. track	8 to 10	1 to 3
" " "	....	2½ to 3½, Dbl. track	12 to 15	5 to 6
Chic., Burl. & Quincy.	Ave. 150	5 to 8, Sin. track	6 to 13*	1 to 3*
Chic., Mil. & St. Paul.	100 to 200	5½ to 9½, Sin. track	2 to 7	1 to 2
" " " "	....	4, Dbl. track	8	1 (min.)
Clev., Cin., Chic. & St. Louis.	80 to 100	5 to 6, Sin. track	7*	4*
" " " " " "	....	3, Dbl. track	7*	4*
Erie.	100 to 140	6 to 7, Sin. track	...	...
"	....	5, Dbl. track	8*	5*
Houston & Texas Central.	140	7, Sin. track	8	8
Illinois Central.	225 to 486	6, Sin. track	7*	...
" "	....	8, Branches	4* to 5*	...
Lake Shore & Mich. Southern.	83 to 170	3½ to 7, Sin. track	10	4
" " " " "	....	3½ to 4, Dbl. track	...	...
Maine Central.	90 to 135	4 to 6½, Sin. track	4 to 6*	3 to 4*
Michigan Central.	....	5, Sin. track	4*	3*
" "	....	4, Dbl. track	...	...
New York Central.	84 to 150, s. t.	5 to 6, Sin. track	5 to 6*	3 to 4*
" " "	60 to 86, d. t.	2½ to 4, Dbl. track	8 to 9*	5 to 6*
" " "	30 to 60, 4 t.	2½ to 3, Four track	11*	7*
N. Y., N. H. & Hartford.	50 to 75 (plus 50, s. t.)	2, Four track	9	5
Pennsylvania.	25	2½, 2 & 4 track	5 to 9	...
Wabash.	Ave. 100	6, Sin. track	7*	3*
"	....	4, Dbl. track	7*	3*
Somerset	90	3 to 6, Sin. track	4 max.	2 min.
Buffalo & Sus.	110	5, Sin. track	8 max.	4 min
Georgia	100	8 to 9, Sin. track	8 max.	6 min.
Ft. Dodge, D. M. & N	160	6 to 7, Sin. track	6 max.	2 min.
La. & Ark.	225	9, Sin. track	9 max.	5 min.

* Including foreman.

Engineers and Roadmasters.

The engineer in charge of maintenance-of-way should have had some practical experience with a section gang or floating gang, so as to understand the work, but he need not be an expert at driving spikes, tamping ballast or putting in switches. He has the more important duty of organizing, directing and supervising the work; he must see that it is done according to instructions and

with regard to efficiency and economy. His subordinates are responsible to him for the details, but this does not mean that he can safely be ignorant of such details. It is for him to study the proper economic relations of track to rolling equipment and traffic, and (in practice) to try to maintain a good and safe track under conditions where these proper relations do not exist. Engineering knowledge and experience are essential in track maintenance work, and within recent years there has been a marked development of the organization of the maintenance-of-way department upon an engineering basis.

The engineer is sometimes regarded as being mainly a surveyor and draftsman, and quite unaccustomed to the handling of work or men. As a matter of fact, however, the engineer is a man of liberal training and generally of wide experience. In such other lines of railway work as construction, reconstruction, changing grades and alinement, bridge renewals, etc., he has to organize his forces, to regulate the expenditures, and to handle and direct large bodies of men. He has also to provide for carrying on the work with rapidity and economy, and with the least interference with traffic. In the maintenance-of-way department he exercises the same capacity and ability. The average cost of labor and material for track maintenance alone is from $600 to $3,000 per mile per year, and represents from 12 to 20% of the operating expenses, as noted in the "Introduction." On a division of 100 miles, the annual expenditure for this work may amount to $60,000 or $300,000, and it will be evident that the officer in charge should be capable of controlling such expenditures wisely and economically. The position of the engineer of maintenance-of-way (or roadmaster) varies on different roads. In some cases he is the executive head of his department, and in others he occupies a more subordinate position.

The roadmaster (called the supervisor on some roads) is the direct head of the track work on his road or division, being the intermediary between the executive officers and the working forces. He should therefore be an intelligent and educated man, and should so act that his men will feel that he is friendly and just in his dealings with them. As to the question whether the roadmaster should be an engineer, or what is vaguely termed a "practical man" (meaning one promoted from the ranks of the section foremen), a very little consideration will make it evident that the former is by far the better fitted for the duties and responsibilities of the position on any important line, unless the organization is such that the roadmasters are under the direct supervision of engineers. Besides the general work of maintaining the track in good condition, the roadmaster should be familiar with the principles of curve and switch work and yard design, the problems connected with ties and tie preservation, the relation of rail sections and weights to wear of wheels and rails, and other matters of similar character. All this, of course, is part of the training of the engineer, who is familiar also with instruments and mathematical work. He must, however, understand the limits to mathematical precision in track work, so that he will not figure out his turnout leads to decimal points, when a little variation may avoid the cutting of a rail and will make no difference in the turnout. In the same way he must understand the limitations which traffic conditions impose upon superelevation, gage on curves, etc. He must, of course, be familiar with track work, or his subordinates will have little respect for him. But while he must be able to direct and govern these subordinates, there is no necessity of his being an expert with the spiking maul or the tamping

bar, any more than the general manager need be an expert at the typewriter, or the mechanical superintendent an expert at firing an engine.

The roadmaster who is a sort of first-class foreman may be thoroughly competent in track work proper, but is apt to be contemptuous of instrument work and mathematical calculations, because he does not understand them or their purpose. The niceties of superelevation and of easement curves are beyond him, and he does not like to see an engineer set stakes for his guidance. For putting in switches and making curves ride easily, he usually prefers to rely upon his eye, rough measurements and "trial and error." He does not comprehend operating conditions and the economic principles underlying his work, and is also liable to prove inefficient in the handling of large numbers of men. He is apt to rely more upon special instructions and personal direction, although general rules and written orders are better for officers directing the work of large bodies of men. Many excellent roadmasters have graduated from the ranks of the section foremen, and may well be in charge of track if under the direction of engineers. A more technical training is required for officers in charge of railway maintenance on important lines under modern conditions.

Great difficulty is often experienced in obtaining men who combine practical and technical training with ability to command, and the railways have looked to the engineering colleges to supply men whom they can educate in the service. The system of apprenticeship introduced on the Illinois Central Ry. by Mr. John F. Wallace is noted later. Other roads have tried a somewhat similar plan, but on a smaller scale. There is no intention of putting young men fresh from college in responsible positions in the track department, over the heads of experienced foremen. They are put in the gang to learn, not to command, and to learn general practice and methods of work rather than to become simply expert sectionmen. The practical training these young men receive, added to their engineering training, is a good foundation for future development in the maintenance-of-way department, and they should be given some promise of promotion. Otherwise they will not care to remain in the roadway service. In view of the steady development of track work on scientific principles, and the valuable class of officers obtained by the combination of scientific and practical training, railway managements can well afford to give the necessary encouragement and opportunities. This does not appear to be recognized, and very little progress has been made in this direction.

In regard to the details of the work of the roadmaster, he is responsible for keeping everything pertaining to the roadway in repair and in proper condition for safe use. He is held responsible for the maintenance and condition of the track on the division, for the safe keeping and proper use of all track material and tools, for the condition of the tool houses, section boarding houses, tanks, pumping stations, etc., and for the proper supply of water to trains. He is also responsible for the condition of yards, right-of-way and station grounds, culverts, trestles, bridges, grade crossings, cabins, platforms, turntables, fences, cattle stations, and all minor structures. The rules and regulations which govern him differ on all roads, in accordance with local conditions and organization. Of course much of the work has to be attended to by the foremen, but it is all included in the roadmaster's responsibility.

He must spend much of his time on the road, but must not neglect proper attention to office duties, such as the checking up of time-books, pay-rolls and records, the preparation of requisitions and reports, and the answering of

letters from other departments. He has usually a clerk for the correspondence and general office work. He must inspect the track partly from the engine or the rear platform of trains; but mainly by going over the sections on his car or on foot, personally interviewing the foremen, and carefully inspecting all new work. He is usually required to pass over a part of his division every day, except when engaged in checking up time-books at the end of the month; and to pass over the whole of the division on foot or on a velocipede at slow speed at least once or twice a month, or oftener on mountainous or dangerous divisions. He should not use the section hand cars for his trips. He must record the dates on which he goes over the division, noting whether the trip was made on foot, by hand car or by train; and must record all important work and its progress. He should be thoroughly posted as to the physical condition of the road and the daily disposition of his forces.

During his trips he must look closely into details of work, and talk frequently with the foremen, calling their attention to defects or bad practice, giving them instruction and advice (but not "nagging" them), and being prompt to award either praise or blame. He must see that new foremen are properly instructed, and that they understand their work and duties. He should see that his orders are thoroughly understood and properly executed, particularly on special or important work, and should inquire of the foremen as to their plans for doing future work. He should never issue orders directly to the laborers, as that tends to injure proper discipline and the respect for the foreman's authority. He must remember that the foreman (and not the roadmaster) is in charge of the gang. He should see, however, that proper and competent men are employed. He should accompany the pay car over his division, to identify the foremen and help settle any disputes.

He must inspect the track to see if it is kept in proper condition as to line and surface, accurate gage, alinement, and superelevation and widening of gage on curves. Frogs and switches must also be examined as to condition and position. The accuracy of the foremen's gages and levels must be occasionally tested. He must see that the proper expansion shims are used in laying new rails, and that new ties and ballast are properly used. Also that all frogs, switches and fixed signals are placed in accordance with standard plans. He must inspect the car and tool equipment, lamps, etc., to see that they are in efficient condition and properly used; and he must see that all supplies are accounted for when requisitions are made for new material. Curve and distance stakes must be noted to see that they are not disturbed, and when they need renewing he must either set them out or report to the engineer. He must see that track signs, bridge tell-tales, mail cranes, etc., are in good and proper condition, and that all notices at farm crossings, etc., are properly posted. Fences, gates and gate fastenings must be noted and reports made of cases where farm gates are habitually left open, or where encroachments are made on the company's property.

The roadmaster frequently has authority over the pumping-station men. He must see that they keep the machinery clean and in order, and that the fuel is properly stored and used. In winter he may also order the foremen to detail men to look after the stoves to prevent freezing up of the water stations. On the failure of water supply at any station, he must send a telegram to the superintendent, and follow this by a written report. He must also report any signals that are out of order. He must see that all buildings and

their surroundings are tidy and in good repair, that boarding houses and boarding trains are kept neat and clean, and that proper food and accommodations are provided for the men. If this is not done it will not be easy to keep good men, and track work will be expensive in consequence of being always in the hands of new men. He must also see that telegraph linemen, fence gangs and bridge gangs are afforded proper facilities and assistance in making repairs. Whenever any structure is being built or work being done on the company's property by other than employees of the company, the facts must be reported, unless it is positively known that proper authority has been obtained. The roadmaster must exercise a general oversight of all work performed on the division by contractors, bridge carpenters, telegraph gangs, etc., in case anything should interfere with the safety of the track. A special inspection of all waterways should be made before the winter or rainy season, any necessary repairs being then made to trestle bents or banks of streams, and all obstructions removed.

Arrangements must be made for carrying out all new work ordered, such as ballasting, laying new rails, putting in switch or interlocking work, laying additional tracks, rearranging yards, reconstructing bridges, etc. The execution of the work should receive close personal attention. The roadmaster has full charge of all work trains on his division, must lay out their work, and make all orders for running them. All orders for work done by construction and material trains are given by him, except in cases of emergency. Insufficient motive power on work trains must be at once reported, as these trains are expensive and require the best motive power to insure their economical operation.

The roadmaster should annually inspect the ties which the section foremen mark as needing renewal, and from this personal examination prepare a requisition for ties needed in the coming year, checking the foremen's counts and requisitions. This estimate must be sent in to the proper officer by a specified date each year. No ties must be removed without his approval, and those removed should not be disposed of until he has seen them. He must carefully examine the requisitions made by the foremen, and ascertain if the articles are really needed and in the quantities asked. Requisitions must be made in writing and sent by mail, the telegraph being used only in emergencies or when delay would result in loss to the company. He must personally receive all materials contracted for, such as rails, ties, ballast, wood, etc., and must strictly enforce the printed specifications for the same, and arrange for handling and unloading or storing. Ties must be properly piled. No material must be piled within 8 ft. of the rails. He must also supervise the storing and shipping of scrap, and its disposal at the scrap yard or pile. He must not permit old material to be sold or given away or otherwise disposed of by the men, and must see that foremen do not allow laborers to remain at the section boarding houses to work for the boarding master.

The roadmaster may be directed to investigate the wear of track material, rails, splice bars or special joints, ties, etc., reporting results from time to time, especially in regard to material under experimental trial. He should mark on a profile of the line all the new rails laid, giving the date, brand, and location. This is in addition to the monthly written reports of rails laid, and enables the engineer to keep account of the wear and life with reference to tonnage. All cases of broken rails in main track should be carefully investigated and reported upon. The rail may be laid aside for examination; and a piece on each side of the break may be cut off, labeled and sent with the report.

The roadmaster is authorized to discharge any section foreman, road watchman, conductor of construction train, or other subordinate, for neglect of duty. He suspends him and makes a report in case of accident resulting from such neglect. Changes of foremen should be made only at the beginning of the month, except for good reason. In reporting the discharge of a foreman the cause should be stated, so that a record of the man's standing can be kept for future reference. A record of all foremen (and sometimes trackwalkers also) employed, discharged, resigned, transferred, promoted, married, deceased or sent to hospital, must be made monthly. A card index is useful in compiling this. When a foreman leaves the service, the roadmaster must see that all tools and other company property are properly accounted for, and must examine his time-books to see that all accounts are correct. New foremen must be carefully instructed in their duties, and must be closely questioned to ascertain if they correctly understand them. While passing over his division, he should carry a book of time vouchers, so as to be able to issue a voucher to any trackman who presents a properly filled time-check. He should require the man to write his name in the blank space provided, so that the voucher may be used as far as practicable to identify the holder. Receipts on standard forms or blanks must be taken for every issue of time cards and for instruction books. These receipts are pasted in alphabetical order in a book.

The roadmaster must see that section foremen, foremen of extra gangs and conductors of work trains are supplied each month with the necessary time-books, diaries, reports of work and materials, board bills, time-tables, etc., and that the use of the blanks is explained to all new foremen. During his trips he should examine the foremen's blanks to see that they are being properly filled in. These returns are sent to him on the last day of the month, and he should examine them carefully, making a mark opposite the names of all men on the check rolls to whom he has issued time vouchers. He then forwards the several reports to the proper officers. The roadmaster must also see that the foremen make reports of accidents, persons or cattle killed by trains, fences burned, etc. (See "Records, Reports and Accounts.")

The roadmaster is required to keep a journal or diary, in which he must enter the location and the dates of beginning and ending of all extra work under his charge; such as grading and laying sidings, changes of line, laying new rails or ties, ballasting, experimental ties or joints, etc. He has also a pocket notebook, in which he records how each trip is made (whether on passenger or freight train, on hand car or on foot), and also any points for record or of use in making up his returns, such as material delivered or required, the number of men employed, etc. As a check on the time of the sectionmen, he should note here the number of men in each gang as he passes. These books should be of a uniform standard size, supplied by the company, and sent to the superior officer each month. Memorandum books and all blanks are obtained from the office regularly or by requisition. He should have his watch inspected once every three months, and should compare it with standard clocks and with the watches of the foremen as often as possible, seeing to it that the foremen take his time as correct. To the roadmaster should be made all applications for detailing men from the section gangs to assist fence gangs, telegraph repair gangs, or bridge gangs, or to clear station grounds and yards.

He must be familiar with the train rules, special orders, etc., and keep in communication with the transportation department. Disregard of signals

by trainmen must be promptly and invariably reported. Locomotives and cars with worn and flat wheels must be reported, as they are very injurious to the track. Also engines which throw sparks during hot dry weather, and are liable to start fires. He must report all defects in bridges, and if necessary make the structures safe until the bridgemen arrive. He must see that the track and roadway are in proper condition for the winter. In times of storm, flood or snow he must keep the superintendent fully advised of the condition of the road, and he must see to the proper distribution and work of trackmen to help the snow gangs on their sections. The roadmaster must closely investigate every accident that occurs on his division, and make a full written report in the proper form, giving the cause of the accident and all information possible. He must be ready at all times, both day and night, to render assistance in case of accident or detention to trains. On receiving notice of a wreck he must proceed to it at once and take charge. Besides removing the wreck, he must put the track in condition for the passage of trains, or build a temporary track around the wreck, all with the least possible delay. Such material as broken rails, axles, etc., which may be of use in determining the cause of the accident, must be preserved. When cars are broken up or burned for removal at a wreck, he should note the type of each car and its number and initials.

Section Foremen.

The section foreman is the most important of the men in the working force, and should be a man of judgment and firm character, so that he can rule his men and get on comfortably with them, while at the same time getting a full amount of work done. He should be able to read and write and keep simple accounts, so as to keep the necessary records of labor and supplies, and to make out his requisitions for material. All reports and requisitions are sent to the roadmaster, and for this clerical work there should be a desk in the section tool house. He is usually required to walk over his section every other day, or at least once a week; this depends upon the season, the length of the section, the condition of the track and the amount of traffic. He has also to make a monthly inspection of and report upon all culverts, trestles, bridges, tunnels, etc., on the section; and must also inspect any such structures at times when they are liable to be damaged by floods or otherwise. He should be subject only to the orders of the roadmaster. Train dispatchers, station agents, claim agents, bridge foremen, tie inspectors, foremen of fence and telegraph gangs, etc., should not be allowed to give orders direct to the section foreman, or to call upon him to supply men for any purpose, except in case of emergency. He should on no account throw switches for trainmen. Where two or more gangs work together on emergency work, as in case of accident, the senior foreman is in charge, subject to the direction of (or until the arrival of) the roadmaster or the wrecking foreman.

As to section foremen working with their men, it may be said that with small gangs, up to five men, the foreman can very well join in the work and still keep a general oversight of it. With eight men or more he should only supervise the work and see that it is being done properly, especially when there are new men to be broken in. A foreman who works regularly as one of the gang is not likely to have their respect or to get the best work out of them. This, of course, depends partly upon the character of the work. Putting in

switches or lining up track will require much watching, while in cutting grass, or in general trimming up (even with a large gang), the foreman can well work with the men, and at the same time watch their progress. It is his duty to direct the operations, and to see that they are carried out properly, and to supervise the track work generally, being careful to have the work done thoroughly and systematically and not at scattered points. On a busy road, and in such dangerous places as tunnels, etc., one of his important duties is to see that the men are warned of the approach of trains, and that they get off the track (and have all tools clear) in ample time, but without waste of time. He must also see that competent flagmen are sent out, if it is necessary for trains to reduce speed. With large gangs, the foreman may be permitted to appoint an assistant foreman, who ordinarily works with the gang, but takes charge in the absence of the foreman. In promotions, the assistant foreman should be given the first chance. The foreman should have power to appoint and dismiss his assistant, making the necessary report of the circumstances. He is, of course, responsible for his ability and for all the work done by him, the roadmaster having nothing to do personally with any trackman below the grade of foreman. The assistant foreman should be selected not only for his technical or practical skill, but also for his executive ability in directing the work and handling the men. He may be given a slight increase in pay over that of the regular laborers, but while some roads find this successful, others find that it causes dissatisfaction among the men. The foreman employs and discharges the men of his gang, and also the bridge and other watchmen on his section, and keeps proper records of all the men and their work. He must treat his men properly, without fear or favor, and must not use profane or abusive language. If they do not live at a section house, he should know their addresses, and arrange a system by which one man can call others in case of emergency at night. He should have authority to employ extra men temporarily during heavy snow, and should have a few extra men assigned him when any extensive switch work, etc., has to be done. It should be his aim not only to keep the section in safe running condition, but to steadily improve its condition and appearance.

He has charge of all repairs on his section, and is responsible for the proper inspection and safety of the track, bridges and culverts. He must see that ditches are clear, that drainage is not obstructed, and that weeds and grass are kept cut along the right-of-way and around trestles; also that ties are tamped, rails properly spiked and jointed, and track in line and surface and in good condition generally. He attends to the fences and signs, and sees that water stations are in order and water barrels at trestles kept filled. He must see that the gang has the proper equipment of tools and supplies, and that this equipment is kept in good condition, properly used, and properly arranged in the section house. He must have a reliable watch, and must daily, if possible, compare it with and regulate it by the clock in the telegraph office at a station or signal tower on his section. He must have a copy of the latest time-table, be familiar with train rules and schedules, and look out for signals on and messages from passing trains. Failure of enginemen to respect his signals or to answer them with the proper whistle must be reported. In case of flood, or heavy rain or wind storms, he should patrol the section with sufficient men to insure safety to trains by setting out signals and torpedoes if any defect is discovered that cannot at once be remedied. Such defect

must be at once reported by telegraph to the roadmaster and superintendent. In case of accident, he must go to the scene with his men, even if it is on an adjacent section. In the absence of other authority, he will detail a watchman to care for freight, etc., at a wreck.

The foreman is supplied with time-books, pay-rolls and diaries, and carries them with him, ready for inspection by the roadmaster at any time. Entries of work and materials must be written up in the time-book, etc., every night for the day just closed, and then added up at the end of the month. The books, board bills, etc., must be properly entered up and certified, and must be sent to the roadmaster by a night train on the last day of the month, or by the first available train on the first day of the new month. On some roads he retains duplicates of these reports. In the check-roll or time-book he enters daily the time worked by each man, and on the diary he records the total time made by the gang. He also makes reports of material used and on hand, of work done, fences or other property burned, and cattle killed by trains. He makes requisitions on the roadmaster for material required.

Should a man leave or be discharged before the end of the month, the foreman gives him a time-check (showing the amount of time he has worked) which he can present to the roadmaster, who will take it up and issue in its place a time-voucher. This is payable by any agent of the company having funds for this purpose. The foreman must require the man to sign his name on the back of the time-check if he can write, and the man may retain this check, which can be used to identify him to the roadmaster or in the pay office. To secure payment to those furnishing board and lodging to track and bridge men, the foreman supplies such persons on the first of the month with blanks for "board due," which they are required to properly fill out and have signed by the men from whom the amounts are due. These blanks are returned to the foreman on the last day of the month, and from them he enters the amount due by each man in the "board" column of the check-roll, opposite the man's name. Different railways have different styles of time-books, blanks, etc., as described under "Records and Reports."

It will be evident that the position of section foreman is one of responsibility, and calls for an active and intelligent man of some education. But with the class of labor now generally employed, it is becoming increasingly difficult to find men suitable for the position, while those who are suitable very often prefer to take positions as brakemen, which offer better chances of pay and promotion. It has been suggested that young men educated in the common schools should be trained in the section gangs with a view to becoming foremen, but the conditions are not such as to offer many inducements. Without skilled and intelligent foremen, it cannot be expected that a good quality of work will be produced by the section gangs. Track work is skilled labor, and the foremen should be paid wages commensurate with the importance of their work and responsibility. As a rule, however, this important matter is ignored, with consequent detriment to the service and the track work.

Trackwalkers and Watchmen.

The entire length of each section is generally inspected at least once a day (except Sunday) by a trackwalker. On important lines this man is in addition to the regular section gang, and he usually starts out in the morning in the opposite direction to that taken by the gang, while on roads having much

night traffic he must also go over the section in the evening. He should start from the section house, so that the foreman may know he is on duty. The time of starting may be arranged so that he can go over the section shortly before the principal trains, and can, perhaps, return by train. In the afternoon he may work for a few hours with the gang, and then go over the section again, returning by train. On double track, he may make a round trip over each track (one by day and one by night), and on four-track lines he passes once over each track. In summer, and in fine settled weather, the trackwalker can join the gang in the afternoon, but in stormy weather he should spend all his time patrolling the section. After a heavy storm the trackwalker and one of the laborers should go over the section and look out for any damage requiring immediate attention.

On the Erie Ry., the trackwalker in summer makes one trip daily over the part of the section which is not covered by the foreman on his way to and from work. In winter or in stormy weather he covers the section twice daily. When tie renewals are being pushed, he works with the gang for the remainder of the day, and in the spring and autumn he spends the remainder of the day tightening bolts and replacing broken spikes. At all times he gives immediate attention to any necessary light repairs of frogs, switches, etc. On branches or lines with light traffic, one of the laborers may act as trackwalker, making one trip and then returning to work with the gang. Some railways employ trackwalkers only at certain seasons of the year, when it is made necessary by reason of heavy rains or other conditions. Other roads do not employ regular trackwalkers, but send a man over each section on a velocipede, leaving all repair work, etc., to the section gang. The foreman is sometimes required to act as trackwalker, but this interferes with his charge of the gang, except that where the traffic is light, he can go over the section after he has first started the gang at work. Where there are many switches or signals, the lampman may act as trackwalker. He makes two round trips over the section: the first in the morning to extinguish the lamps; the second in the afternoon to fill, trim and light the lamps. In such case the foreman or a laborer should make an extra trip in bad weather. On the Boston Elevated Ry., the track is inspected during the day by 11 trackwalkers, each with about 1½ miles of line. They replace and tighten bolts, replace worn spikes, and grease the guard rails on curves. Repair work is done at night.

The day trackwalker looks out for broken rails and burnt ties, raises low joints, picks up loose material and places it at the side of the track, tightens loose bolts and spikes or puts in new ones, and examines frogs, switches and switchstands. He must see that cars on sidetracks are clear of the fouling points. He also notes broken or defective signals, broken fences, farm gates (reporting any that are habitually left open), looks out for fire on bridges and trestles, and sees that the water barrels on wooden structures are kept full. He may in general "do anything and everything to protect the railway from accident." After a heavy storm he must be specially observant, and look out for evidence of washouts or of slides of banks or cuts. In winter he must look sharply for broken rails after a very cold night. He must also clear snow where it is packed about frogs, switches, guard rails and the flangeways of crossings.

The day trackwalker is ordinarily equipped with a track wrench, a spike maul, 2 red flags, torpedoes, and a few bolts, nuts and spikes in a bag. The

Southern Pacific Ry. requires a few angle bars and bolts to be kept out on the section for the convenience of the trackwalker. On the Chicago & Northwestern Ry., the day man carries a spike maul, and looks out for the general condition of the track; there is no night trackwalker. On the Louisville & Nashville Ry., the day man carries a wrench, spike maul, 5 spikes, red flags and 4 torpedoes; he tightens bolts and spikes. The night man carries a red lamp, white lamp, 4 torpedoes and a spike maul. On the New York, New Haven & Hartford Ry., the day man carries a maul, wrench, pocket flag, 3 bolts, 6 spikes and 8 torpedoes. There is no night man. The trackwalker should be considered as an inspector, and not as a repair man; he looks out for the general condition of the track, but does only emergency work, particularly the replacement of bolts and spikes. Any general defects he reports to the foreman. The night man is not expected to do any work, except where the track is actually unsafe. He may carry a lantern having red and green glasses in an interior cylindrical case, this being turned by the bail of the lantern to show the desired color.

When the trackwalker finds any place unsafe for the passage of trains, he must place a red flag (in each direction on a single-track line) at a distance of 90 rails or 15 telegraph poles, and place a torpedo on the rail. The torpedo should be on the rail on the engineman's side of the track, and the flag on the same side of the track, 3 ft. from the rail. Where the block system is in force, the trackwalker's beat may be between certain block towers, and he may be required to enter the tower and sign his name and the time in a record book, the signalman also signing the record. Watchmen at special points may also be required to report at a block tower or telegraph station at stated times. Trials have been made with watchmen's clocks carried by the trackwalkers. Boxes are placed at certain points and each has a key attached by a chain; when this is inserted in the instrument, it makes a record on a chart. The chart will then show at what time the man reached each of the several points.

It will be seen that the trackwalker has an important and responsible position, which should be filled only by an experienced and trustworthy man. It is sometimes assumed that his work is principally to look after loose bolts, but in the main the amount of trackwalking is independent of the work done in tightening the bolts. Some roads do not permit the trackwalker to touch the bolts unless he sees something wrong, but this does not warrant any reduction in the trackwalking. Too much care can hardly be taken in guarding the track, and in watching it in time of storms to prevent accidents as far as possible, and at least to prevent accidents to trains. With track of average condition, the trackwalking usually costs more on curves than on tangents, unless more attention is given to the maintenance work on the latter. Watching also costs more, as an engineman cannot see ahead on a curve, and in case of a storm or flood, it may be necessary to station a watchman in a cut on a curve, when it would not be necessary if the track were on a tangent.

Any particularly dangerous spots, such as tunnels, loose rock cuts, sliding slopes of cuts or banks, rock cuts in winter, and culverts and trestles in time of flood, should be guarded by watchmen. The man should be provided with lamps, flags and torpedoes, and, if necessary, with tools (a pick, shovel, ballast hammer, wheelbarrow, etc.), and some sticks of giant powder to break up rocks that may fall on the track. If watchmen are stationed permanently, cabins should be provided. These men must be of sufficient experi-

ence to appreciate the responsibility of the post and to be relied on in case of emergency. On the Erie Ry., the watchmen on rocky divisions are supplemented by a "rock gang" in charge of a foreman. This is composed largely of quarrymen, who are experienced in climbing and in detecting and removing loose or dangerous rocks.

Grade-crossing watchmen or gatemen have usually nothing to do with the track, except to see that the flangeways are clear and that the planks are securely fastened to the ties. Bridge watchmen must see that water barrels are kept full on wooden bridges and trestles. They must follow every train and extinguish any hot cinders that may have fallen from the engine, and at the same time look for signs of sparks lodged in the upper part of the structure. They must keep combustible material cleared from the vicinity of the bridge, keep abutments, copings and bridge seats clean, and report any bulging or sign of cracking and undermining of the abutments or masonry. They must also examine the structure and report any decay or defect, slackening of nuts, loose rivets, etc. They should observe the structure during the passage of trains, noting specially if trains cross at too high a speed. Every train must be signaled by a white flag or lamp if all is safe. They should prevent all persons, other than employees, from walking over the structure. Drawbridge tenders must look after the locking and other gear, and the signals or gates, reporting promptly any sign of defect in the structure or the machinery. Bridge watchmen and drawbridge tenders may be required to do incidental work when not engaged in their special duties.

Force and Labor.

The number of men employed upon each section depends upon the condition of roadbed and track, the season of the year, and the amount of traffic. As shown in Table No. 18, the maximum gang is about 10 or 12 men and a foreman in summer on a single track. The minimum is reached on roads where in winter the foreman alone is required to look after 6 to 10 miles of single track, with occasional help in case of snow. The average, however, is 5 to 8 men on single track in summer, and 2 to 4 men in winter. With a small gang, the section should not be too long, as in case of finding a broken rail, etc., there may not be time to flag both ways or to get help from an adjacent section. As an average, it is estimated that 1 man per mile of single track, or 1½ men per mile of double track, with a foreman and trackwalker to each section, will be force enough to maintain the track in proper condition if the material is good. Where sidings exist, it is usual to take two miles of important siding or three miles of unimportant siding as equivalent to one mile of main track. As a rule, it is not economical, though sometimes necessary for financial reasons, to reduce the force to less than a man to two miles on ordinary sections, as such a reduction leads to deterioration and a roughly riding track, with eventually a heavy expenditure for repairs due to insufficient expenditure for maintenance.

In the spring, the track must be surfaced, lined and gaged, have new ties put in, and low joints raised, etc. As soon as the frost is out of the ground, therefore, the gang should be filled up to the full number that the foreman can handle, say 10 to 15 men. With the heavy work done before the increase of traffic in the summer, the force may be cut down before farm work and harvesting begin to take the men away. The track can then be maintained

during the summer with a force of about 1 man per mile, which is the lowest economical average for ordinary work. It is not wise to allow the track to get in bad condition in summer for want of enough men to maintain it, as a larger force than usual must then be employed in the autumn, or winter, when work cannot be done to advantage. In the autumn, there is ditching and cleaning to be done, and the track put in condition for the winter. The force is then reduced to the minimum, but should be reduced gradually, so that work in hand can be safely and thoroughly finished. With the rails, ties and ballast in good condition, 2 or 3 men may be enough for the watching, clearing and occasional shimming. The foreman should have authority to employ extra men for handling snow when necessary.

The number of switches and frogs on the section has a considerable influence on the amount of work and the number of men required, varying, of course, with the amount of traffic. It has been considered that 15 switches and frogs on an ordinary section would necessitate an extra man. This refers to both main track and small yards under conditions of moderately heavy traffic, and the number of switches and frogs requiring an extra man would be less than 15 in the case of a busy yard or terminal. Where yards occur, the section must be shortened or the force increased, but at a large yard it is best to have a separate gang under a yard foreman.

Many railways employ extra or "floating" gangs to do fencing, relaying rails, switch work, ballasting, general surfacing, ditching, tile drainage, etc. This gang has a boarding train. Where a good class of labor is employed, however, it is better to have all ordinary work done by the regular gang. There is then no divided responsibility as to the character of the work. A good foreman and gang should be able to do all ordinary switch work. The frequent appearance of the floating gang is apt to put the regular gang in the habit of expecting to avoid all heavy work, and this is not conducive to efficiency. With the poor grade of labor now employed, the conditions are somewhat different, and it has been suggested that it would be economical to maintain a floating gang of picked men, provided with a comfortable boarding train, working under a good foreman, and paid good wages. The difficulty is to get and keep such men at the wages generally paid by railways for such work. In the system tried on the Ohio River Ry., and already noted, the heavy work was done by permanent floating gangs on 30-mile sections. The floating gangs of the New York Central Ry. are composed of 15 to 50 men with a foreman and assistant foreman, and with a timekeeper where there are more than 30 men. On some roads there is an "apprentice gang" in charge of a foreman, and the new men are given proper instruction in this gang, instead of having to pick up their knowledge as best they can while working with a regular gang. Men trained in this way are valuable, and will often make good foremen.

There is often a tendency to do any extra or unfinished work on Sunday, but this is a reprehensible practice. It spoils the men's temper, and is detrimental to good work and discipline. The men cannot keep up a high standard of efficiency, nor can they have respect for foremen who insist upon Sunday work. The practice should be forbidden, and the foremen made to understand that the rule will be strictly enforced. Men require a day of rest, for its physical and mental as well as moral effect, and if they are required to work for 13 days they will not do a fair day's work during each of the last 6

days. It is also an expensive practice to spend 6 days in preparing for a large amount of work to be done on Sunday, with all the section gangs that can be conveniently got together, as the work is generally done with a rush. In case of emergency or accident, the men should, of course, go to work at once. But it is not necessary to do ordinary work on Sunday, except in special cases on busy suburban lines, terminals, or where the traffic is exceedingly heavy. It must also be remembered that the sectionman has few opportunities of spending time with his family and friends, and to deprive him of these even on Sunday is not only unfair, but is opposed to the permanent interests of his employers. The man (whether foreman or laborer) is best to be depended upon if he gets fair treatment and fair pay for a fair day's work.

A bad policy which is frequently in evidence is that of employing the lowest and cheapest grades of labor on the track. Good results are not to be expected from such men, and the employment of foreigners who cannot speak the language, but have to be communicated with by signs, is certainly not conducive to good work. Inefficient and careless men should be discharged without delay, whether foremen or laborers. The improvement in the grade of labor rests almost entirely with the railway companies, for good men are usually to be had at reasonable wages. It has, however, been pointed out many times that the higher officers very generally fail to recognize the importance of the track, and to realize the economy of proper maintenance. Consequently, cheap labor is employed, and the track forces are reduced and their wages kept down. There is a strong sentiment of discontent among sectionmen and foremen at the lack of remuneration and encouragement; and it is hard to keep a permanent gang where any tramp or laborer is considered good enough for track work. The trackmen's work is little regarded; yet if these men relax their vigilance or fail in their duty, not all the skill of the engineer, the care and faithfulness of the enginemen and train crews, or the elaborate equipment of the trains, can give a satisfactory train service or prevent accidents. A weak spot, a neglected loose joint, a defective switch or frog, an overlooked broken rail, or spikes not properly redriven, not only make a roughly riding track but may cause a wreck with disastrous results, involving expenditures for repairs and compensation.

Track work requires skilled labor to a very large extent. The fitting up of joints, putting in switches and switch leads, giving the required elevation and transition on a curve, lining and surfacing track, and tamping ties to a firm and uniform bearing, is work which comes within the daily routine of the trackman, but for which common labor is certainly not efficient or economical. It has been shown by investigation that the permanence and easy-riding condition of track depends very largely upon the proper tamping of the ties. But such work cannot be done properly by inexperienced men, who work mainly by "sheer strength and awkwardness." It would be economy in many cases to organize a permanent force, as is done in Europe. Trackmen who understand their work are valuable, and should rank as skilled laborers, and the railways should endeavor to retain their services by encouragement in pay and promotion. Intelligence, skill and faithfulness are required, as well as muscular ability, but the first requirements can hardly be expected from the grade of men whom the foreman too often has to employ. Men who hold permanent positions (contingent upon merit), and have perhaps a pension in view as a reward for long and faithful work, have more regard for

the interests of their employers and are more apt to try to educate themselves in their work. But good men will not stay permanently when they are overworked and underpaid, are liable to immediate and unexpected dismissal, see little encouragement in the future, and can find plenty of better positions in other lines of work. The roadmaster and section foreman can best understand these conditions, and their advice in the matter is rarely heeded. Unskilled laborers may be employed temporarily for extra work. But it is as false economy to have a constantly changing gang of green sectionmen as it would be to follow the same practice with enginemen, trainmen or machinists. Such men will use more time and material in doing bad work than experienced men will use in doing good work.

Men should not be employed who are under age, elderly, weak, incapacitated, or deaf; or who suffer from consumption or other diseases. The foreman must not excuse habitual neglect of duty, but should promptly dismiss or suspend unfaithful employees. No man should be discharged without cause or for the purpose of making place for another. On most roads the use of intoxicating liquors by employees while on duty is strictly forbidden, and this rule should be most rigidly enforced. Men who habitually drink too much when off duty should be dismissed. Smoking, while on duty, should also be prohibited. There should be a rule prohibiting the offer of testimonials or presents to superiors, or the acceptance of such by the superiors.

The maintenance-of-way departments of some railways have introduced the Brown system of discipline. The demoralization which results from punishment by suspending men from duty is well known, to say nothing of the hardships for those dependent upon the men. Under the Brown system, when a rule is broken, orders are disobeyed, or any irregularity occurs which calls for discipline, it is noted on a bulletin issued to roadmasters and foremen. The bulletin may also be posted up in stated places. No names are given, but the man who is at fault usually receives a marked copy, and a record is kept for each man. The disgrace of being bulletined is felt by the average man, and the moral or disciplining effect is probably much deeper and more effectual than that of suspension. Men are discharged when disciplining fails and their records are bad.

Work-Train Conductors.

The conductor of a work train is usually appointed by the roadmaster, subject to the approval of the division superintendent, and must obey orders from the superintendent in regard to safe movement of the train. He must see that all ditching, ballast and boarding cars are in good running order, that the boarding cars are clean and neat, and that good, substantial food is furnished to the men. He must be familiar with the time-table and train rules, with the rules and instructions issued to track and bridge men, and also with the work of maintenance of track. Ditches must be cut according to the direction of the section foreman. He must see that care is taken in unloading material, that new ballast is cleared to leave a proper flangeway along the rails, and that skids are used in unloading rails. In distributing new rails, he must note in a book the initial and number of each car, and the number and lengths of rails on each car.

He must notify the roadmaster when ordered to distribute material, such as ties, rails, ballast, etc., so that the roadmaster can notify the section fore-

men and be with the train while working on his division. He makes a weekly report of work done, materials used, delays to work, insufficient power of engines furnished, etc. When the train is delayed and likely to be held for some time, he must put the gang at work ditching, weeding, or clearing station grounds and yards. He must understand that his desire to get the work done and his train out of the way must not lead him to do hasty or careless work. The train should always lay over at a telegraph station at night.

The foreman of the work-train gang should be the conductor, sharing responsibility with the engineman, as in regular train service, for a conductor who has no other duties outside the train is apt not to work in harmony with the foreman, who is interested in and held responsible for the day's work. A foreman who acts as conductor can arrange his work to the best advantage. He should be an expert track foreman, and be provided with an assistant foreman, and also with a timekeeper if he has a large gang. (See also "Ballasting" and "Work Trains.")

Minor Track Officials.

Master Carpenters.—These usually report to and receive orders from the roadmaster. They have charge of the repairs of buildings, bridges, trestles, stations, water tanks, pumping stations, etc. When making ordinary repairs, they must see that the main tracks are unobstructed, or if it is necessary to obstruct them, they must obtain an order from the superintendent and must protect themselves by flag in the usual way.

Yard Masters.—These report to and receive instructions from the division superintendent (and also from the trainmaster or other officer in charge of transportation), and they also comply with instructions from the station agents. They usually have to do only with the handling of cars, but are sometimes also in charge of the track work of the yard.

Switch Tenders.—These report to and receive instructions from the station agents, while in yards they report to and are under the direction of the yard master or station master.

Bridge and Building Department.

This department is frequently connected more or less closely with the maintenance-of-way department. It has charge of the construction, maintenance and renewals of all structures, and one of its important duties is to plan means for promptly repairing and rebuilding wrecked or damaged structures. Turntables, track and stock scales, ash pits, water tanks, wells, pumping plants, mail cranes, coal-handling machinery, etc., are frequently in charge of this department. There is usually a general yard for lumber and piles, while emergency stocks of timber are kept by the master carpenters at points on the divisions. The department is generally in charge of a superintendent of bridges and buildings, who reports to the roadmaster, resident engineer or superintendent. Under him are the bridge foremen and master carpenters. Examples of the organization on individual roads are given at the end of the chapter, and particulars of the work are given under "Bridge Work."

Signal Department.

This department is very often allied with the maintenance-of-way department, and the charge of signal apparatus of every description on the road

(switch targets, and train-order, block and interlocking signals) should be concentrated in the signal engineer. He should have a suitable staff of inspectors, repairmen, signalmen, etc., and the employing and discharging of these men (including the signalmen) should be in his hands. The signal engineer usually has charge of construction, but the maintenance and operation are often in charge of division officers. In view of the important relation of signaling to the operating service, it would seem to be more systematic and economical to have construction, maintenance and operation all under the direct charge of the signal engineer, so that the equipment can be kept in proper condition without having to refer matters to various departments. It also avoids difficulties due to securing uniform practice and action by the various division superintendents. The practice on some railways is described below.

The respective responsibility of track supervisors and signal supervisors must be clearly defined in regard to such matters as the maintenance of insulated joints and the maintenance of throw of interlocked switches. These matters relate equally to track and to signaling. Variation from the proper amount of throw of switch will affect automatic signals or the locking apparatus.

Chicago & Northwestern Ry.—The signal engineer reports as follows: 1, To the engineer of maintenance on maintenance matters and on construction orders issued by the general manager or vice-president in charge of operation and maintenance; 2, To the general superintendent on operation; and, 3, To the chief engineer on construction orders issued by the vice-president in charge of construction. The division engineers have charge of all signal matters on their territories, reporting to the signal engineer. They look after the work directly, except that on the four largest divisions there are supervisors of signals, reporting to the division engineers. Where the automatic block signal system is in use, there is under the signal supervisor a maintainer with about 20 miles of double track. Under him (where there are interlocking plants) is a helper (who does the interlocking work), a batteryman, and lampmen. On outlying divisions there is usually one repairman who has a sufficient number of assistants for the work. He reports directly to the division engineer.

Cincinnati Southern Ry.—The signal department includes automatic blocking, interlocking plants, train-order signals, switch and signal lamps, crossing gates, and electric-light plants. The superintendent of signals reports to the general manager. The signal engineers, with 100 miles each, report to the division superintendents and the superintendent of signals. Repairmen, with 10 miles, serve as batterymen and report to the maintenance foreman.

Pennsylvania Lines.—The signal engineer reports to the general superintendent of each system for the work done on that system, and acts under his direction. He prepares plans, specifications and estimates for signal equipment, consulting with the division superintendents as to the plans. He has charge of the erection work connected with interlocking and fixed signals, and inspects them from time to time to see that standards are adhered to in their maintenance. The maintenance of the interlocking and fixed signals on each division is in charge of a supervisor of signals, who reports to and receives his instructions from the engineer of maintenance-of-way of the division. He reports weekly to the signal engineer the condition of the work in his charge, on forms provided for that purpose. The supervisor is responsible for the proper working of all interlocking apparatus and other signals on his

division. He must make all necessary and ordinary repairs, but must not make any change in the locking, or in any part of the apparatus or appliances, without instructions from the signal engineer. He must make examinations, as often as may be necessary, of all interlocking apparatus and signals. Where these are in charge of foreign companies, he must not allow any changes to be made without instructions from the signal engineer. The signal repairmen report to and receive instructions from the signal supervisor.

Systems of Organization.

Illinois Central Ry.—The engineering department is in charge of the chief engineer, who is responsible for both construction work and the maintenance of the entire fixed property, including tracks, bridges, buildings, turntables and water supply. Interlocking and block signals, however, are under the jurisdiction of the superintendent of telegraph and signals. The chief engineer reports to the general manager concerning maintenance matters, and to the vice-president in charge of construction and traffic in regard to construction matters. His staff consists of a chief engineer of maintenance-of-way, and a principal assistant engineer; the latter has charge of construction work. The chief engineer of maintenance-of-way has an engineer of bridges, a general foreman of waterworks, a supervisor of scales, a chief gardener and a chief timber inspector. The last has charge of the treating and creosoting of timber and ties. Reporting to the engineer of bridges are two assistant engineers of bridges, a superintendent of bridges, a superintendent of buildings, an architect, and a supervisor of fire protection. The engineer of bridges and the general foreman of waterworks also assist the principal assistant engineer on new work under construction in their respective departments.

Ordinary maintenance of track, bridges and buildings and water supply is handled by the division organization, the superintendent having jurisdiction over all matters on his division. To assist him in roadway matters he has a roadmaster, who has an assistant engineer, track supervisors, a supervisor of bridges and buildings, and a waterworks foreman. The section foremen and the bridge and building foremen report to the supervisors. The superintendent reports to the engineering department through the general superintendents. On operating matters, he reports to the vice-president in charge of operation.

Roadmasters have charge of divisions varying from 225 to 486 miles. Supervisors of bridges and buildings cover the same territory as the roadmasters. Track supervisors average 100 miles of road. Section foremen have from 6 to 8 miles. On main line, with single track and gravel ballast, a section gang consists of a foreman and 6 men per 6-mile section, one of these men usually acting as trackwalker. This force is reduced on the less important lines with gravel ballast to a foreman and 4 men. On track with earth ballast (which is used only on unimportant branch lines), the gang consists of a foreman and 3 or 4 men. Additional men are employed as needed to put in extra ballast, lay new rails, clean ditches, and do other important work which cannot be taken care of by regular gangs. The average force allowed is 1 man per mile in summer and about 1 man per 2 miles in winter. Floating gangs (or extra gangs) are used to lay rails, widen ditches and banks, put in ballast where an extra amount is required, and any other work which cannot be taken care of by regular section gangs.

The Illinois Central Ry. for some time employed graduates from engineering schools in the capacity of engineering apprentices, the original intention being that they should divide their time between assisting the division engineer and working with the section gangs in order to permit them to acquire a practical knowledge of track work as well as engineering work. This, however, did not work out satisfactorily, as it was found that chainmen and rodmen were needed to such an extent, on account of the large amount of construction work under way, that it was necessary to take these men into the engineering corps before they had acquired the knowledge of track work which it was intended they should have before promoting them. Supervisors are promoted from assistant engineers and also from the ranks of section foremen.

Southern Pacific Ry. (Pacific System).—The organization of the engineering and maintenance departments is as follows: (A) Chief engineer and assistants, who have to do only with construction of new lines and with important changes on existing lines, as far as track matters are concerned; (B) Assistant chief engineer, reporting directly to the general manager; (C) Two engineers of maintenance-of-way, reporting to the general superintendents of their respective districts on ordinary maintenance matters, and to the assistant chief engineer (either direct or through the general superintendent) on matters pertaining to standard plans and important repair and renewal work. The assistant chief engineer is assisted by a signal engineer in charge of construction and maintenance of block signals, and by a bridge inspector and assistant bridge inspector. To the district engineers report the resident engineer of each superintendent's division (either direct or through the superintendent) on all matters concerning the maintenance or renewal of roadbed, track, bridges, buildings, etc. All such work (as well as construction work on operated lines) is carried on under the direct charge of the resident engineer, in whose office the pay-rolls for his department are made and accounts kept for reporting to the auditor at specified times. He is assisted by an assistant engineer acting as superintendent of buildings and bridges, a signal engineer in charge of signal work on his division, and as many assistant engineers for general work as the volume of such work warrants. Each superintendent's district is divided into roadmaster's districts, each being in charge of a roadmaster reporting directly to the resident engineer on matters pertaining to maintenance of roadbed and track. The roadmaster is assisted by section foremen in looking after track matters, and by foremen in charge of carpenter gangs caring for bridges and roadway buildings.

Atchison, Topeka & Santa Fé Ry.—The chief engineer of the system is a staff officer, and reports to the president. He has charge of all construction and extension work. All changes of line and grades are in charge of the several chief engineers, who submit important plans and estimates to the chief engineer of the system for approval before submitting them to the operating department for authority to do the work. The maintenance-of-way work, ballasting, repairs to track, timber trestles, care of bridges and buildings and maintenance of signals, are all under the direction of the general superintendents. The jurisdiction of the signal engineer includes block and interlocking signals, train-order signals and switch signals. All switch, signal and train-order lamps are under the supervision of an inspector who reports to the signal engineer. There is also a tie and timber department which has charge of the purchase, treating and distribution, and the keeping of all

records of tie treatment and renewals, etc. The track foremen report to the roadmasters, who report to the division superintendents, who in turn report to the general superintendents. On each division there is a general foreman of bridges and buildings, who reports to the division superintendent, and who has charge of the maintenance and repairs of trestles, building and water service. The carpenters and painters report to this general foreman. The roadmaster's divisions average 140 to 150 miles. The shortest is 106 miles, all main track; the longest is 250 miles, nearly all branches.

Chicago, Burlington & Quincy Ry.—Engineers of maintenance-of-way report to general superintendents, and have the same territory as the latter (from 1,200 to 1,800 miles). They have jurisdiction over division superintendents on maintenance-of-way matters. The district engineers are in the engineering department proper, and have to do with operating and maintenance-of-way matters in an advisory capacity. Division engineers, roadmasters, bridge superintendents and master carpenters report to the division superintendent. The signal engineer and the bridge engineer report to the engineer on eastern lines. A roadmaster's division covers about 150 miles, and track sections from 5 to 8 miles, according to the importance of the line. The number of men to a section in spring ranges from 6 to 12 (according to the importance of the line and the availability of men). In winter it varies from the foreman alone to a foreman and 2 men; this may be increased in an open winter and according to necessities. Floating gangs are employed for rail laying, surfacing, bridge construction, or any large jobs of either maintenance or construction work along the line. On some divisions there are permanent gangs of this kind, and on others the gangs may be disbanded in the winter.

Pennsylvania Ry.—The chief engineer of maintenance-of-way reports to the general manager, and is one of the four "cabinet officers" assisting the latter (chief engineer of maintenance-of-way, general superintendent of motive power, general superintendent of transportation, and superintendent of telegraph). He is assisted by an engineer of maintenance-of-way, and is represented on each of the grand divisions by a principal assistant engineer. The latter is in turn represented on each operating division by an assistant engineer, to whom the supervisors report. The supervisors (or roadmasters) are engineers, each in charge of about 25 miles of line and having an assistant. Subordinate to them are the track foremen, whose sections average 2½ miles on double-track and four-track lines. On each division there is a master carpenter, who looks after general repairs to bridges, buildings, etc.; he reports to the assistant engineer. The maintenance-of-way department has general charge of the track, bridges, buildings, turntables, water and coaling stations, signals, etc. It is also charged with the maintenance of standards, and watches the developments or improvements in track construction. The chief engineer has charge of all engineering construction work, including the preparation of plans, estimates and specifications for new lines, bridges and buildings. He also keeps records of the cost of all construction work, and has charge of the distribution of rails for both construction and renewals. He reports to the second vice-president.

Baltimore & Ohio Ry.—The maintenance-of-way is under the operating department. The chief engineer of maintenance-of-way reports to the general manager, and each engineer of maintenance-of-way has supervision of the maintenance in the territory of the general superintendent to whom he reports.

The division engineers have charge of from 95 to 240 miles. They report to the division superintendents, while the supervisors and master carpenters report to them. The inspector of maintenance and the tunnel inspector report to the chief engineer of maintenance-of-way. The signal engineer and the engineer of bridges and buildings report to the chief engineer. The number of men in the section gangs depends entirely upon local conditions, and there is no permanent organization of floating gangs.

New York, New Haven & Hartford Ry.—The maintenance-of-way is under the engineering department, and directly under the engineer of maintenance-of-way, who reports to the chief engineer. The engineer of construction and engineer of bridges also report to the chief engineer, under whose direction are made all changes and renewals of roadway, bridges, buildings, docks, etc. The division engineers, signal engineer and superintendent of buildings report to the engineer of maintenance-of-way. The roadmasters and the bridge supervisors (in charge of bridges, turntables, and coal and water stations) report to the respective division engineers. Carpenters, masons and painters report to the superintendent of buildings. The length of roadmasters' divisions on double track is from 50 to 75 miles, with various lengths (up to 50 miles) of single track in addition. The New York Division includes 61 miles of four tracks, and 11 miles of six tracks. On four-track lines, the sections are 2 miles long. The number of men (including foreman) in the section gangs on important lines is 9 in the spring (with full force) and 5 in the winter. On less important lines, 7 and 5 men; and on unimportant side lines, 6 and 3 men respectively.

Erie Ry.—The organization is on the division system. The chief engineer has charge of all construction work, and of bridges and buildings. Indirectly, he also has charge of maintenance-of-way, as he establishes all standards relating to track and signals, and these cannot be changed without his consent. The engineer of maintenance-of-way has charge of all matters pertaining to maintenance of track, bridges, buildings, water supply, etc. The division engineers report to him on these matters, and he reports directly to the general superintendent. Plans for all new work and important structures are prepared by the chief engineer, who either assumes direct charge of construction, or refers it to the engineer of maintenance-of-way, and thus to the division superintendents, who in turn refer it to the proper officers. There are two general superintendents, each having an engineer of maintenance-of-way; and each division superintendent has a division engineer. The latter has under him engineers and rodmen, and also the roadmasters (or supervisors), track foremen, carpenters, masons, and all necessary mechanics and laborers.

Michigan Central Ry.—The chief engineer has charge of all construction, and of the maintenance of track, bridges, buildings, water supply, real estate, interlocking, and signals of all kinds. The division roadmasters report to the division engineer, who reports to the assistant chief engineer. The general scheme of organization is as follows:

Officers.	Reporting to	Officers.	Reporting to
Asst. Chief Engineer....	Chief Engineer.	Foremen of Repairs.......	Asst. Roadmasters.
Prin. Asst. Engineer....	Asst. Chief Engineer.	Foremen of B. & W. S....	Supt. Bldgs. & W. S.
Division Engineer......	" " "	Masons and Bdg. Carps....	Div. F., B. & W. S.
Bridge Engineer........	" " "	Carps. and Painters.......	" "
Signal Engineer........	" " "	Asst. Bridge Engrs..........	Bridge Engineer.
Supt. of Bldgs. & W. S...	" " "	Div. Foremen of Bdgs.......	" "
Assistant Engineers.....	Division Engineers.	Signal Supervisors...........	Signal Engineer.
Roadmasters..........	" "	" Inspectors............	" Supervisors.
Assistant Roadmasters..	Roadmasters.	" Maintainers..........	" Inspectors.

Delaware, Lackawanna & Western Ry.—Maintenance-of-way is under the engineering department, and the chief engineer reports to the president. The principal assistant engineer, signal engineer, division engineers, superintendents of water service, and superintendents of bridges and buildings, all report to the chief engineer. The general roadmaster and the roadmasters report to the principal assistant engineer.

Philadelphia & Reading Ry.—Maintenance-of-way is under the operating department, the engineer of maintenance-of-way reporting to the general superintendent (who reports to the vice-president). The chief engineer reports directly to the first vice-president. Track supervisors and signal supervisors report to the division engineers, who report to the division superintendents. Resident engineers (on construction work only) report to the chief engineer. The signal engineer reports to the engineer of maintenance-of-way and to the general superintendent.

Hocking Valley Ry.—The engineer of maintenance-of-way reports to the general superintendent, who is the highest official having jurisdiction over maintenance-of-way. Supervisors report to the division engineers, who report to the superintendents. The chief engineer reports to the president.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—The assistant chief engineer is at the head of the maintenance-of-way department, and reports to the chief engineer. The latter (reporting to the general manager) handles both maintenance and construction, but devotes most of his time to the construction work. There is an engineer of track and roadway, who acts mainly in a consulting capacity, and reports to both the chief engineer and the assistant chief engineer; he issues instructions to the superintendents, who direct the engineers of maintenance-of-way. On each division the maintenance is under the operating department, the division superintendent being in complete control. The track supervisors and the supervisors of bridges and buildings report to the engineers of maintenance-of-way, who report to the superintendents. The supervisor of water service reports to the chief engineer.

Pere Marquette Ry.—Maintenance-of-way is under the operating department. Roadmasters report to the division engineers, who report to the superintendents. The bridge engineer reports to the chief engineer, who reports to the general manager and general superintendent.

El Paso & Southwestern Ry.—Maintenance-of-way is under the engineering department as to plans, forms and methods; and under the operating department in execution. The resident engineers report to both the engineer of maintenance-of-way and to the division superintendent. The chief engineer and the engineer of maintenance-of-way both report to the general manager. The roadmasters and general bridge foremen report to the division superintendents.

Gulf, Colorado & Santa Fé Ry.—The resident engineers report to the chief engineer, who reports to the second vice-president and general manager. The roadmasters report to the division superintendents.

Houston & Texas Central Ry.—The resident engineers report to the division superintendents, and the engineer of maintenance-of-way reports to the general superintendent.

CHAPTER 18.—TRACKLAYING.

The engineer in charge of tracklaying runs in the alinement upon the completed roadbed, rectifying minor inaccuracies, especially in the curves. The anchor bolts for steel bridges should not be set until this final accurate alinement has been made. He has a copy of the field notes locating the position of each intersection, P.C. and P.T., the stakes by which these are referenced, and notes of the curvature and length of curve. In many cases he finds that the curves will not fit, and the P.C. must be moved backward or forward until the P.T. falls on the given tangent. The line is monumented as soon as possible after this work. Pieces of rail about 4 ft. long, driven down with their tops a short distance below track level, make convenient and satisfactory monuments; a cross cut on the top marks the exact point.

In general, center stakes are driven at intervals of 100 ft. on tangents and 50 ft. on curves, or sometimes 25 ft. on transition curves. Many track foremen consider that centers may be 300 or 400 ft. apart on tangents, but it is pointed out elsewhere that instrument work rather than "sighting" should be employed in lining first-class track. In any case, stakes should be set at intervals of at least 200 ft. on tangents and 50 ft. on curves, and at each end of every spiral or transition curve. For a double-track railway, the center-line stakes are sometimes set between tracks, and the tracklayers are provided with measuring boards with which to get the proper lateral distance for the line rail of each track. In some cases, the engineer prefers to run a center line between the rails of each track, or outside of the rails and close to each track. At sidetracks, the switches and turnouts must be carefully laid out, and substantially supported on a good bed of ballast. The center stakes should be set for sidetracks, and the positions of head blocks indicated. The turnout curve may be laid out with a transit, or by means of a tape, with calculated offsets from the main track, as described in the chapter on "Switch Work." On bridges and trestles, the track centers may be marked by tacks at intervals of about 20 ft., and offsets made at the distance to the edge of the rail flange. A chalk line is then struck between these offset points. In tracklaying, one rail is first laid with its edge set to the chalk line, and is then securely spiked; the other rail is set in position by the track gage.

Before tracklaying, the roadbed should have been properly dressed by the contractor to the exact subgrade, or the subgrade plus any allowance for settlement which has been decided upon. This is done by having dressing or trimming stakes set by the engineer for the use of a small grading gang furnished by the contractor after the first rough grading has been done. If the work is not done by the contractor, it should be attended to by a small grading gang working ahead of the tracklayers and under the orders of an engineer. Failure to have this properly done in advance results in delay to the tracklaying gang, and probably in defective track. In some cases the roadbed is inclined on curves to approximately fit the superelevation.

The engineer in charge of tracklaying has to see that arrangements are made for keeping the contractor supplied with the proper amount of material, and also to see that the materials are properly used, and that the work is

properly done. He should specially look after matters of detail, except, perhaps, in these now rather rare cases when a long line of track has to be laid with the greatest possible rapidity. As a rule, the railway company supplies all material, and a supply train for delivering this material at the end of the completed line, ready for the contractor. The latter undertakes the entire work of tracklaying (including the distribution of the material from the stated points of delivery), subject to the supervision of the company's engineer. Similar arrangements are made when the company does the work with its own men. The full number of ties to each rail should be laid in advance of the rails. In bolting up the joints, the specified spacing between rails must be strictly adhered to, and only iron spacing shims should be permitted. (See the chapter on "Rails.") During this work care should be taken to see that spikes, bolts and other small material are not lost or wasted. After any necessary tamping or filling under the ties has been done, the ballast trains are run upon the track and unloaded, and the ballast is put in place and tamped. Then comes the final lining and surfacing. The amount of care bestowed upon this depends upon the character of the road, but for first-class track, of course, all work will be carefully done. As few trains as possible should be run over a partly ballasted track, so as to prevent surface kinking of the rails, a defect which it is almost impossible to remedy subsequently. In tracklaying work on the Oregon Short Line, daily reports are made by the engineer in charge. The report is made in triplicate in a book 9×12 ins., having two lines of perforations. The report shows the position of the work by 100-ft. stations, the length of main and side track laid, switches and turnouts put in, weight of rail, number of ties per mile, etc.; also, the weather conditions and the causes of any delays. The engineer in charge retains the stub report, and sends the two detached reports to the engineer of construction and the chief engineer. On the back of this third report are shown the alinement and profile and the location of sidings and other features.

The management of tracklaying requires a clear head, good judgment, and a faculty for handling large bodies of men and keeping them all at work together without driving them or causing them to interfere with one another. This applies to the foremen as well as to the engineers, and it is further to be noted that tracklaying trains (like work trains) should be handled by powerful engines in good condition. In regard to the speed of the work, it is rarely practicable to maintain a high rate of progress continuously. Uncompleted bridges or sections of grading are likely to stop work occasionally, so that the work of tracklaying is largely governed by these conditions rather than by the means of carrying it on as rapidly and economically as possible, irrespective of delays, etc. The highest records have been made in open prairie work, where speed was a prime consideration. In many cases, too much has been sacrificed to speed, and on important new lines quality rather than quantity of construction should govern.

Tracklaying by Hand.

The material train, with a properly arranged quantity of track supplies, is run to the end of the completed track, and the work is usually begun by hauling the ties by teams and distributing them alongside the roadbed. The tie gang then places the ties, spaces them accurately, locates the joints by a 15-ft. pole, picks out the large ties for joints where this is required, and then

lines up the ties on one side of the roadbed by means of a cord stretched between stakes set half a tie length from the center stakes. On curves, this is first stretched as on tangents, and then curved by measuring from it the middle and quarter ordinates for the degree of curve. The ties should not be laid too far ahead of the rails, or the joint spacing may require rehandling of the ties under the rails, which is troublesome. The full number of ties should be laid at once, and not a few ties to each rail length, leaving the other ties to be slipped in under the rails, as the rails are likely to be kinked by the running of the material train over such a track. The ties should, if necessary, be adzed to give proper seats for the rails.

Rails are then run from the train to the head of the track on a push car or horse car. The rail gang takes off two rails, half bolts them at the heel joint, sets the head ends to gage at the front end by a grooved track gage, and secures them by a few spikes. It is usually specified that the rails must be laid with the maker's brand on one side (usually outside) of the track. If the rails are bent or kinked in handling, they should be straightened before being laid. Rails for curves of over 2° or 3° should be curved in a rail-bending machine. Care must be taken not to let the joints run ahead, but to keep them truly square, or else exactly opposite the middle of the opposite rail, according to whether track is laid with square or broken joints. To maintain this even spacing on curves, some of the inner rails must be short. A good plan is to have a number of rails cut to a length of 29 ft. 6 ins. at the mill, these short rails having their ends painted so that they can be readily distinguished. These rails are kept separate from the regular 30-ft. rails, and a certain supply of them is carried on the material train. The foreman of the tracklaying gang is provided with a list of the curves and the number of short rails required on each curve.

The joint or splice gang then bolts up the rail joints, and the spiking gang sets the rails to gage and completes the spiking. In this latter work the rails on the line side of the track should be spiked first, and the others adjusted by the gage. The outer spikes should be driven in the forward side and the inner spikes in the rear side of the tie. About 75 to 80 men would be required to lay a mile of track per day by this method. Greater progress is expensive, unless the ties can be hauled a long distance ahead with teams and properly distributed. By distributing them far ahead, however, the joint ties are likely to require shifting when the rails reach them. When it is difficult to secure expert spikers, the speed of the work can be increased by using bridle rods to maintain the gage in front of the train. The spiking gang behind the train removes these bridles, which are carried to the front again.

A convenient arrangement is to have a gang of 55 men in charge of two foremen, and equipped with three rail cars, a horse, and two portable turntables. One turntable is placed at the loading and the other at the unloading end of the track. An ordinary load for the rail car is six rails, and a full supply of ties, splice bars, bolts, nuts, washers and spikes for that number of rails. If the driver reaches the front before the unloading gang has unloaded all the material from the first car, he puts the turntable in position ready to haul the car off when empty. If the gang finishes unloading before he arrives, it runs the empty car off, ready to be hauled back. On returning to the loading end with the empty car, the driver puts the turntable on the track, and runs the car off onto a pair of ties. He then hitches the horse to the loaded

car and goes to the front, while the loading gang runs the empty car back into position for loading. With such a gang of good men under a smart foreman, a mile of track may readily be laid in two days. The distribution of the men is as follows:

9 Loading truck from construction train.
8 Unloading truck at head of track.
1 With horse hauling the truck.
4 Spacing ties and lining them with a cord.
6 Splicing joints.
27 Spiking (3 sets of 9 men each).

The cost of tracklaying and surfacing (exclusive of ballast and ballasting) varies, of course, with the locality and the character of the track. On Western roads it has averaged $250 to $500 per mile. One of the lowest records was that of the Atchison, Topeka & Santa Fé Ry., in 1888, when tracklaying at the rate of two miles per day was done with a gang of 164 men, at $170 per mile for tracklaying labor proper; and $60 per mile for surfacing, with a gang of 84 men. The total cost per mile, including expenses for engineers, engine and train crews, etc., was $248. On the Western Division of the Canadian Pacific Ry. remarkably rapid work was done across the prairies, the records being 4 miles per day in 1882, and 6 miles in 1883. The daily average was from 2½ to 3½ miles. The tracklaying gangs where fast work was done were composed as shown in Table No. 19.

TABLE NO. 19.—TRACKLAYING GANG; CANADIAN PACIFIC RY.

Unloading rails from cars *	12	Teams hauling ties	33
Loading rails on trucks *	12	Unloading and distributing ties	8
Unloading and laying down rails *	24	Spacing ties	4
Bolters	15	Readjusting displaced ties	2
Spikers	32	Rail truck boys (to 6 horses)	4
Nippers	4		
Spike peddlers and tie loaders	32	Total	182

* Eight men in each of these gangs were handling joints, bolts, etc.

The following is a description of the methods employed in 1892–1893 in the construction of the Minneapolis, St. Paul & Sault Ste. Marie Ry. across North Dakota, to connect with a line of the Canadian Pacific Ry. from Pasqua (on its main line) to Portal, on the United States boundary. The 30-ft., 72-lb. rails were spiked to ties 6 ins. thick, 7 to 10 ins. wide and 8 ft. long, spaced 2,816 to 2,992 per mile, or 16 to 17 per rail length. The rails had square three-tie supported joints, spliced by 40-in. angle bars with six bolts, but the engineer questioned the utility of splice bars exceeding 22 to 26 ins. in length. The width at subgrade was 16 ft. The tracklaying and surfacing were done by the railway company, and the construction train was made up as follows:

1. Pioneer car.
2. Store car.
3 & 4. Dining and sleeping cars.
5. Kitchen car.
6. Dining and sleeping car.
7. Feed car.
8. Water car.
9 to 16. Flat cars with rails and spikes.
Locomotive.
17. Telegraph material.
18 to 32. Box cars with ties.

The first eight cars formed the boarding train, which was always kept at the head of the track. The material train, composed of the other 24 cars, was brought up during the night from the last sidetrack, and stopped about 400 ft. from the boarding train. The tie cars were then cut off, and the rail and telegraph cars were moved up and coupled to the boarding train, making the train as described. The ties were distributed by wagons, Fig. 196, being unloaded from the box cars by chutes, Fig. 197. The inner end of the chute had a bar of 2-in. pipe, and was secured at any desired height in the doorway by turning the pointed screw fitting within the bar. Fig. 198 shows the

method of using the chute. The rails were handled on push cars, Fig. 199; these had 20-in. wheels with 7-in. treads, and at each end were rollers, as shown. Planks were nailed beneath the two transoms so as to form a box for splice bars and kegs of bolts and spikes.

Work commenced at 7 a.m., the teams hauling ties from the five rear cars onto the grade (16 ft. wide), where the tie gang unloaded, placed and spaced them. From both sides of cars Nos. 15 and 16, the rail men unloaded 100 rails and the necessary fastenings, dropping them upon the roadbed. The train then moved back 400 ft. The 100 rails were then loaded on two rail cars or push cars; each carried 50 rails, with splice bars, bolts and spikes. The cars were hauled to the end of the track by horses. Ten men on each side of the first car ran forward with a rail and dropped it in place, together with a pair of splice bars and six bolts for the joint. Immediately the rails were dropped, one man threw a hook gage, Fig. 200, over their outer ends, and the horse then pulled the car forward 30 ft., one man on each side stopping the car with an iron stop block, Fig. 201. Two more rails were then quickly run out and dropped as before. At every fifth and sixth rail length, alternately, a 200-lb. keg of spikes was thrown off. These kegs were broken open by the two spike peddlers, who took 100 lbs. of spikes in their boxes, Fig. 202, and placed two spikes on each tie.

The two "front strappers" put on the splices, adjusted the expansion spacing by metal shims, and fastened the two center bolts. The other strappers followed and completed the joints. Four "front spikers" with a gage followed close to the front strappers, and spiked the track at joints, centers and quarters. The spiking was finished by 12 other spikers. For each two spikers there was an assistant or "nipper" who held the tie up to the rail with a bar, using a block as a fulcrum. When the rails from both cars were nearly all in place, the train was again run forward; 100 rails and the necessary fastenings were thrown off as before, and the train again ran back out of the way. The rail-car gang would drop 100 rails (1,500 ft. of track) in from 25 to 30 minutes. The cars were brought forward at about every second move of the train, or oftener if the nature of the ground required it. At about 11.30 a.m., the ties remaining in the box cars were thrown out on the ground, to be picked up and loaded on the wagons. Then the empty cars, Nos. 9 to 32, were run rapidly back to the material sidetrack and exchanged for loaded cars arranged as before. These were brought to the front in time for work at 1 p.m. An additional locomotive, at the rear of the train, was employed when the grades required it.

Telegraph material was thrown off car No. 17 at each forward movement of the train. The poles were of cedar, 6 ins. diameter at the small end and 25 ft. long, set 5 ft. in the ground, and these were spaced 30 to the mile. The wire was stretched from a reel placed on a small hand wagon, pushed by men. Tents were carried on the boarding train to be set up at night for quarters for extra men, or to shelter the horses in cold weather. Detachable feed boxes were slung on the sides of the boarding cars. Surfacing gangs followed the tracklayers, and surfaced the track from the shoulders of banks or sides of cuts, so as to make a safe roadway and prevent bending of the rails or splices before the ballasting was done. These gangs usually numbered 40 to 45 men under a foreman and sub-foreman. They lived in boarding cars set out on temporary sidetracks, and went to and from work on hand cars.

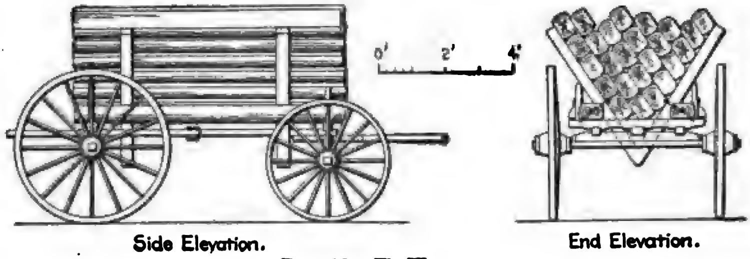


Fig. 196.—Tie Wagon.

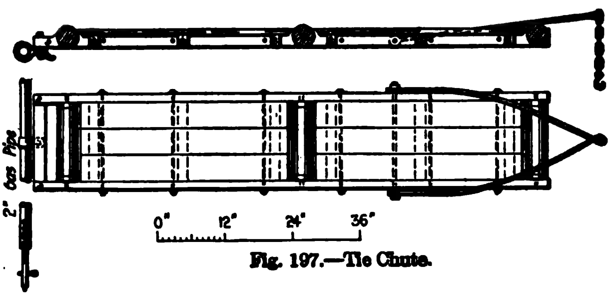


Fig. 197.—Tie Chute.

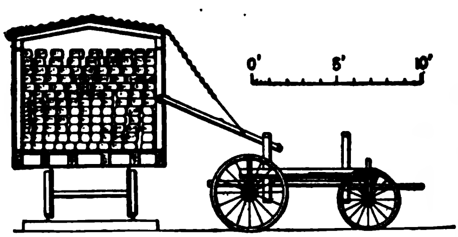


Fig. 198.—Unloading Ties by Chute.

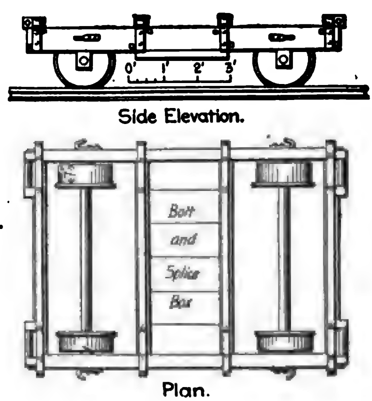


Fig. 199.—Rail Car for Tracklaying.

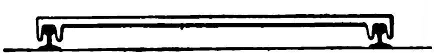


Fig. 200.—Tracklaying Gage.

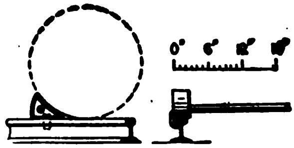


Fig. 201.—Stop Block for Rail Car.

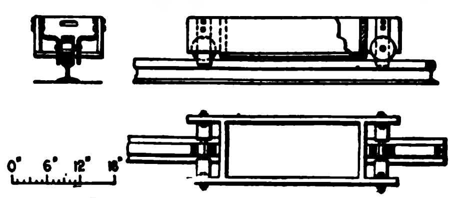


Fig. 202.—Spike-Peddler's Car.

TRACKLAYING APPLIANCES ON THE MINNEAPOLIS, ST. PAUL & SAULT STE. MARIE RY.

Mr. Rich, the chief engineer, stated that the company had used tracklaying devices, and in swampy, very hilly, or timbered regions they were very serviceable. But in a dry, open country, like North Dakota, the method above described enabled the work to be advanced at higher speed and at no greater cost per mile. The average advance was three miles per day, and on some occasions over four miles of track were laid in 10 hours with the force named below. By increasing the force without regard to strict economy, five or six miles might be laid in a day. The entire work was in charge of a superintendent of construction, stationed at the siding nearest to the head of the track, who ordered and forwarded material and gave general instructions. He had a business car, a clerk (who was also a telegraph operator), and a cook. The telegraph line was in working order at the end of the track every night, the instrument and operator being located in car No. 1. The general foreman had control of all trains and employees working at the front, and in case of emergency could at any time communicate by telegraph with the superintendent of construction, a few miles at the rear. Material tracks from 2,000 to 2,500 ft. long were laid at intervals of about 10 miles, unless regular stations were to be provided at shorter distances. The tracklaying force was as given in Table No. 20.

TABLE NO. 20.—TRACKLAYING FORCE; M., ST. P. & S. S. M. RY.

	Foremen.	Laborers.		Foremen.	Laborers.
General foreman, on horseback	1	..	Men unloading ties from cars (3 to each car)	..	15
Rail-car gang (who dropped rails and fastenings)	1	22	Men unloading rails and fastenings from cars	..	4
Strappers (who adjust and bolt splices)	..	6	Telegraph gang	1	8
Spike peddlers (distribut. spikes)	..	2	Telegraph operator	..	1
Tie-spacing gang	1	12	Drivers of rail-car horses	..	2
Men lining ties (rope and stakes)	..	2	Blacksmith	..	1
Men spacing joint ties (with 30-ft. pole and tie pick)	..	2	Night watchman	..	1
Men leveling grade out by tie wagon	..	4	Cooks	..	2
Spikers	..	16	Baker (worked only at night)	..	1
Nippers (hold up ties for spikers)	..	8	Waiters and helpers	..	5
Tracklining gang	1	6	Storekeeper	..	1
Teamsters for tie wagons	1	40	Total	6	161

All baking was done during the night by an extra force of cooks. The cooks, baker, waiters, helpers and storekeeper were employed by a contractor, who boarded the men for $3.50 per week, furnishing all supplies and bedding. The amount for board was deducted from the wages of the men and paid to this contractor. The equipment of the boarding train, kept at the head of the track, was as follows:

No. 1. Pioneer car; double deck. This contained a blacksmith shop, 10×12 ft.; storeroom, 8×12 ft., for heavy tools, harness, etc.; office for general foreman, 12×14 ft., with three sleeping berths and telegraph office; two sleeping apartments on the upper floor; and a tool box under the car. A platform in front, supported by rods from the top, carried extra splice bars, bolts and spikes. Under the platform was fastened an extra rail car.

No. 2. Store car; double deck. Besides two storerooms for clothing and provisions, there were sleeping berths for the cooks, a sleeping apartment above, and a tool box underneath.

No. 3. Dining and sleeping car; double deck. On the lower floor were two dining rooms; one for the foremen and guests, the other for teamsters and telegraph gang. Above were separate sleeping apartments for the teamsters and the telegraph gang, and underneath was a tool box.

No. 4. Dining and sleeping car; double deck. On the lower floor was the

laborers' dining room, and above was a sleeping apartment with berths for 32 men. Underneath was a tool box.

No. 5. Kitchen car. The kitchen and provision room was 12×32 ft., with two cooking ranges. Underneath was a tank supplied by hose from the water car; pumps at the sinks delivered the water as needed.

No. 6. Dining and sleeping car; double deck. On the lower floor was a laborers' dining room, and on the upper floor was a sleeping apartment with berths for 32 men. Underneath was a box for wood for fuel.

No. 7. A box car carrying feed for the horses, and coal and wood for the use of the cooks. No. 8. A flat car, having at each end a wooden tank of 2,000 gallons capacity, the tanks being connected by a pipe. No. 9. A flat car loaded with rails, bolts and spikes. No. 10. (Car No. 17). A flat car loaded with telegraph material. The double-deck dining and sleeping cars were 34 ft. long over the body, with a 3-ft. platform at one end; the width of the body was 12 ft., and the dining room and sleeping rooms had a clear headway of 6 ft. 3 ins. The sleeping room had two rows of berths on each side. The kitchen car was of similar dimensions, but had only one floor. The bodies of these cars could be removed by unbolting four corner bolts which secured the floor beams to the car sills.

In the extension of the Atchison, Topeka & Santa Fé Ry. from Stockton, Cal., to Point Richmond, in 1899–1900, the tracklaying work was organized as in Table No. 21. The rails were laid with broken joints, and there were 17 ties per rail on tangents, 18 on curves up to 3°, and 19 on curves over 3°. The first piece of work was practically level; the second had a descending grade of 1%, with curves at short intervals. The tracklaying train each morning carried material for one mile of track, and was made up as follows: Pioneer car, 3 cars of ties, 2 cars of rails, 3 cars of ties, 2 cars of rails, tool car. The train was pushed to the front, a certain amount of rails and ties unloaded, and the train then pulled back. The material unloaded was then placed on cars hauled by a horse, the rails ahead and the ties behind. The ties were carried around the rail car and distributed, after which the rails were thrown in place and the rail car and tie car moved forward. This was repeated until the supply was exhausted. Strappers and spikers followed the cars and partially spiked and bolted the track before the train came upon it. As soon as the material was laid, the train was again pushed forward and another lot unloaded.

TABLE NO. 21.—TRACKLAYING; A., T. & S. F. RY.

Track laid	10.74 miles.	16.6 miles.
Average per day	2,846 ft.	3,503 ft.
Maximum per day	5,400 "	4,500 "
Rails	62½-lb.	75-lb.
Number of men, average	44.6	47.9
Number of men for maximum day's work	57.0	52.5

Foreman	1	Distributing spikes	1
Subforemen	3	Spacing ties	2
Strappers	4	Spacing rails	2
Rail-car men	10	Back bolting	2
Spikers	8	Tie carriers	2
Nippers	4	Picking up material	1
Tie lineman	1		
Lining ties	2	Total	52
Tie plater	1		

The track was laid with ties which had been tie-plated in the material yard before being sent to the front. The tie-plates under the joints had spike holes punched to a different spacing from those used elsewhere under the rail, and as the track was laid, it was necessary for a man to take out the ordinary plates and replace them with the joint plates. He also had to replace any

tie-plates which had been shaken out during transfer to the front. The rails were all curved in the yard before being forwarded to the front. The rail-car men attended to unloading the rails from the train and loading them on the rail cars. They also handled the fittings, such as splices and spikes, until it came to distributing, when an additional man was used for distributing spikes. The "heelers" at the rear end of the rail unloaded from the car the splices at the proper places. The surfacing was done by a following gang taking material from the corners of the bank, throwing it between the ties and using it for tamping. In some cases, however, material such as sand for surfacing purposes was hauled onto the track, there being no ballast which could be obtained at hand. The boarding train was set out at a sidetrack.

Tracklaying by Machinery.

Tracklaying machines are now very extensively used, not only on large railway contracts, but also on lengths of 50 to 100 miles. For long stretches of work and in difficult country (rugged or swampy), especially where teams cannot be used to distribute the ties ahead in the usual way, machine tracklaying is very extensively employed and permits great rapidity, with a saving in cost over the ordinary method. It is also preferable in laying new track, as it avoids the cutting up of the roadbed by teams hauling ties. The title "tracklaying machine" is rather incorrect, since the machine does not lay the track, the general principle of the system being that the ties and rails are run to the front of the supply train on rollers or tramways laid along the cars, and are delivered to the tracklaying gang from a frame projecting in front of the first or pioneer car, this car or "machine" forming the head of the material train. In recent improved designs, however, the rails are run out by overhead trolleys on a frame extending as a cantilever ahead of the car, and are then lowered in place. This simplifies the labor problem and dispenses with the large gangs of men required to handle heavy rails. The supplies for a day or half a day are carried on the train and delivered where wanted, the train being moved 30 or 60 ft. at a time, according to whether the rails are laid singly or in two-rail lengths. Sometimes only half the number of ties to a rail length are laid ahead of the train, leaving the rest to be put in by a tie gang following the train. This somewhat reduces the close work of a large gang, but while a single train may perhaps not do very much damage, it is better practice to put in the full number of ties before the train runs over the track. There will then be less liability of injuring the rails or joints by surface kinking. The speed depends largely upon the ability to keep the machine supplied with material. On the Rio Grande, Sierra Madre & Pacific Ry., in 1897, the work averaged 2½ miles per day, and could have been increased to 3 miles if material had been supplied, but in this case teams were used in addition to the machine. It is possible to put on enough men to lay more track by hand than by machine, but this is usually more expensive. Mere rapidity of work is now rarely a first consideration.

Holman System.—The tracklaying train, Fig. 203, has ordinary flat cars fitted on each side with tramways 20 ins. wide, having a series of iron rollers. These tramways are 30 ft. long, and are carried by iron brackets set in the stake pockets of the cars. The sections are flexibly connected between the cars, and extend the full length of the train, having a slight inclination towards the front end. The ties and rails on the cars are thrown upon these tram-

ways and rolled down to the front, where men receive them and place them in position on the roadbed. The ties (moving endways) come down on one side of the train, and the rails on the opposite side. The tie tramway ends in a chute, supported by a wire cable, which runs out 35 ft. in front of the

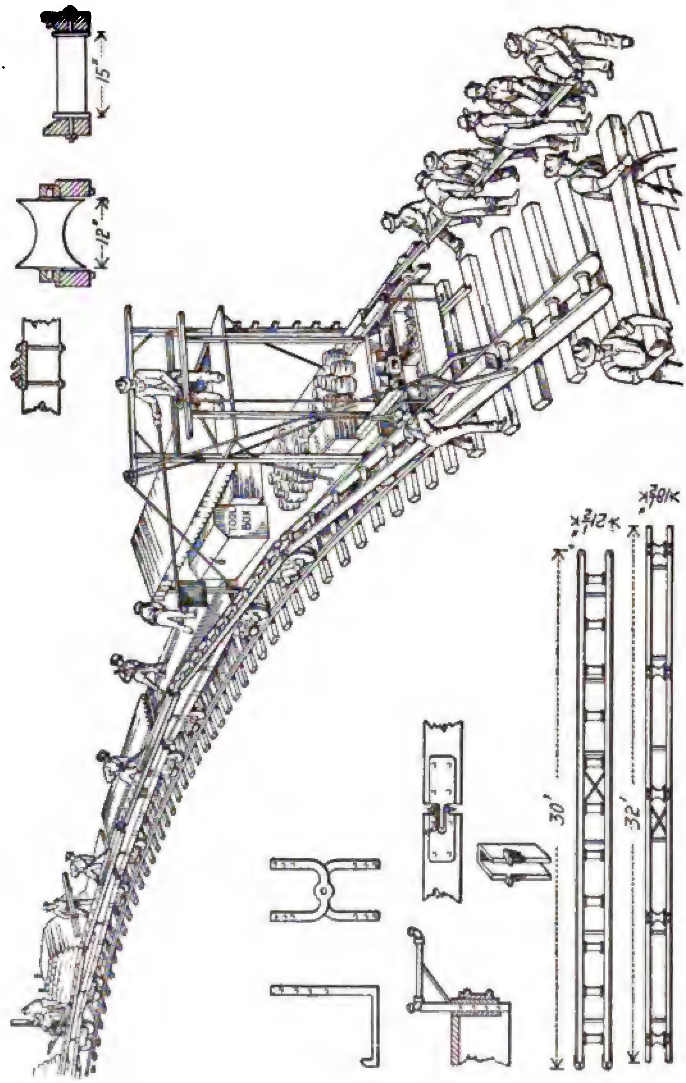


Fig. 203.—The Holman Tracklaying Machine.

train, so that the tie gang is one rail length ahead of the rail gang. The tie chute is adjustable laterally, so that on curves the ties are always delivered at the proper distance from the center line, while on bridges and trestles they can be delivered near the center of the track. As each rail comes down the

chute it is seized by the rail gang, placed upon the ties and pushed back against the previous rail, the expansion spacing being arranged by the joint gang. The rails are usually delivered on the left side, the left rail being the "line" rail, from which the position of the other is gaged. A recent modification of the machine has a cantilever frame on which travel trolleys by which the rails are run out.

The pioneer car at the head of the train is fitted with an elevated frame or trestle, from which the chutes forming the end of the tramways are suspended. On this frame rides a man who signals the engineman when to push ahead; he also handles the brakes on the car. This car is kept at the head of the track. The tracklaying train is made up at the yard or siding where material is stored. It usually consists of three cars of rails (at the front) and six cars of rails, followed by the locomotive. On reaching the end of the completed track, the pioneer car is coupled to the head of the train, the brackets are set in the car pockets, and the roller tramways fitted to them. This takes about 15 minutes. At the same time, the kegs of bolts and spikes are placed on the pioneer car, ready for distribution. The train will carry sufficient material for a half-day's work, or from ½-mile to ¾-mile of track. From 1½ to 2 miles of track per day can be laid with this equipment and a force of from 40 to 60 men, provided the railway company can deliver the material at the front fast enough. More than this can be done under favorable conditions. This includes the full supply of ties, laying the rails in position; joint, quarter and center spiking; and putting on the splice bars with two bolts to each joint. This leaves the track in safe condition for the construction train, and the balance of the work is finished behind the train. As fast as each rail length is laid, the train moves forward one rail length. When all the material is laid, the tramways and brackets are removed from the flat cars and laid at the side of the track. The pioneer car is uncoupled, and the train goes back to the material yard, where another set of cars has been loaded.

On the Northern Pacific Ry., with the Holman system, 11,200 ft. of track have been laid in 10 hours with 63 men. On the Washington County Ry., the highest record for a 9-hour day was 10,000 ft. full tied, spiked and lined. This was done with a force of 110 men. Two train loads of material were laid each day, each train consisting of about three cars of ties and three cars of rails. The second train was ready at the nearest siding at noon, when the trains were exchanged. The ties were distributed about two rail lengths ahead of the rails, and the full number was always laid, as it was considered that with machine work it was cheaper to do this than to put in only half the ties in front and to lay the rest behind the train. There were usually about 90 men in the gang, distributed as follows: 26 running ties out; 3 running rails out; 8 receiving and placing rails at the front; 6 carrying ties to the front; 2 lining; 2 bolting up splice bars; 30 spiking; 4 lining and spacing ties, and 6 helping, waiting on the others, etc. On the Billings extension of the Chicago, Burlington & Quincy Ry., the speed with the Holman machine and a force of 85 men was 1½ miles per day, at a cost of about $100 per mile. There was a morning and an afternoon train, each made up of four flat cars of rails and four flat cars of ties ahead of the locomotive, and four box or flat cars of ties behind the engine. The track was laid with 65-lb. rails, and 18 ties to a rail, or 3,168 ties per mile. The track was half-tied in front of the engine, the balance of the ties being put in by lifting the rails and slipping the

ties into place. Curves of 1° to 16° were laid without any special arrangement. The force was distributed as shown in Table No. 22.

TABLE NO. 22.—TRACKLAYING GANG WITH HOLMAN MACHINE; C., B. & Q. RY.

43 Men in Front of the Engine.		43 Men Behind the Engine.	
1 Foreman.	1 Lineman.	1 Straw boss.	2 Spike peddlers.
1 Heeler.	1 Poleman and marker.	2 Tie unloaders.	4 Bolters.
4 Spikers.	4 Tie carriers.	2 Tie placers.	1 Gage carrier.
2 Nippers.	2 Tie spacers.	4 Tie spacers.	1 Water boy.
1 Rail thrower.	1 Tram tender.	2 Rail lifters.	2 Spike pullers.
1 Spike peddler.	1 Bolt trimmer.	12 Spikers.	4 Liners.
1 Gage carrier.	2 Bolters.	6 Nippers.	
1 Expansion driver.	2 Strap carriers.		
2 Fork men.	8 Tie pushers		
4 Rail pullers.	2 Tie loaders.		
1 Water boy.			

Harris System.—The tracklaying train has 34-ft. flat cars specially equipped. The cars for carrying ties have 8-ft. ties laid across them and projecting alternately on opposite sides of the car so as to carry a running plank for the men. Upon these a track of 2-ft. gage is laid in the middle of the car. Each car for carrying rails has five long timbers (11-ft. bridge ties) laid across it, the tops of these being cut away at the middle to allow the rails of the 2-ft. tram track to be laid upon ties of the same height as those on the other cars. Between the rails, at each timber, is an iron roller $3\frac{1}{2}\times10$ ins. The tops of the rails of the tram track are flush with the tops of the timbers, so that the rails piled on either side can be thrown easily upon the rollers. These form a runway for conveying rails to the front. There are no rollers on the tie cars. Splice bars are attached to the ends of the tram rails by a single bolt through the end hole in the rail and the plates, the plates on adjacent cars projecting toward each other. When work is in progress, the gap is filled by short rails having the base cut off for 18 ins. at each end, the web dropping into the slots formed by the splice bars projecting from the fixed rails on each car. These connecting rails are cut short enough to avoid jamming when all slack in car couplings is closed up. They require no fastenings, and are retained at the front for use on each train. The tracklaying rails are piled upon each side of the cars, so as to clear the tram track. Each car carries the proper complement of splice bars, stored in the open spaces between the cross-ties; spike and bolt kegs are loaded in the runway between the rail piles and are afterwards moved to the end of the car, preparatory to unloading when the train reaches the front.

The pioneer car has, in addition to the rail rollers and tie tramway, a pair of stringers extending the tram track about 20 ft. ahead of the car. The stringers are elevated to clear the men working on the track, and the outer end is supported by rods passing over a gallows frame about 10 ft. high at the middle of the car. A cross beam on the ends of the stringers has a casting which projects downwards and carries a double-ended roller about 2 ft. below the level of the car deck. This roller is about 14 ft. from the end of the car for laying single rails, or 22 ft. for laying two 30-ft. rails spliced together.. A nose piece deflects the rails to either side. Two portable "dollies" are used at intervals of 15 ft. ahead of the car. These are light frames, about $3\frac{1}{2}$ ft. high, with sills resting across the ties; each has a roller 4×18 ins. on the top. The 2-ft. gage tram for the ties has a platform 5×9 ft., and is fitted with a double frame; when the wheels strike the chock blocks on the front end of the stringers, the top frame slides forward about 3 ft. on rollers.

This shifts the load forward, causing the car to tilt and dump the ties on the roadbed. The car then tilts back, and the men slip the top frame back into position while returning for another load. As the ties are carried crosswise, the men on the rail cars have to move back onto planks laid on the ends of the 11-ft. timbers to allow the tram to pass. Another truck may be used to convey the ties part of the way from the tie cars to the front, the load being transferred to the dump car by a loading device at the meeting point. This truck is very low, and has at its front end an incline up which two men slide the ties to the side frames of the loader. The dump car runs under the ties, and trips the loader, the side frames dropping and laying the ties across the car. The tie trams and the pioneer car are kept at the head of the track. For ordinary work, the full number of ties may be laid in advance; but for fast work, half the ties are put in behind the train, though this practice is not to be recommended.

Material for a mile of track is loaded as follows: 5 flat cars with 72 rails each, 5 flat cars with about 300 ties each, and 5 to 8 cars with about 1,500 ties in all. The engine pushes the train to the head of the track. The pioneer car is coupled to the front car; the short connecting rails are adjusted in the tie-tram track; spike and bolt kegs are taken from the runway and stored on the ends of the cars. The tie-tram is then run back and loaded. One man on each of two of the rail cars throws two rails onto the rollers. Four men pull these four rails forward to the pioneer car, two more men on the rear end of that car putting on the splice bars and two bolts, and putting in the expansion shims. The man on the rail car also throws off the splice bolts and spikes, as required. Meanwhile, 16 to 18 ties (for two rail lengths) have been loaded on the tram and the rail men step aside to let it pass. It dumps the ties on the ground, and the tie gang distributes them. When the tram is run back, the four rails (bolted together in pairs) are run forward over the dumping frame rollers onto the portable "dollies" until the rear ends are clear of the car. The rails on the line side are lifted from the rollers and dropped on the ties, thrown back against the rails already laid, and fastened to the latter by one bolt through the splice bars previously bolted to them. While the gage rails are being laid in the same way, 4 men are spiking the line side at 3 or 4 ties per rail (quarters and centers); 4 other men follow with gages and spike the gage rail. At the same time 2 men are putting expansion shims at the heel joints of the two-rail section and half-bolting up these joints, and 2 more are putting the splice bars on the front end of the section, while others are moving the dollies ahead. The train then moves ahead 60 ft., bringing the front end of the pilot car about 8 ft. from the end of the rail, when another load of ties is dumped as before.

Meantime, men in two of the cars at the rear of the train drop off eight or nine ties per rail length at each move of train, while a man on the ground sees that the ties do not go down the embankments, and also that the proper number are dropped. A few men with picks and jacks then put in the back ties. They are followed by the back bolters, spikers and lining gang. Thus the track is only half-tied, half-bolted and quarter-spiked in front of train. Material to complete the work is distributed from the train as it advances, and the back gang keeps the work completed close up to the rear of the train. For laying track with broken joints, the ties are carried 15 ft. further ahead, and the four rails (two lengths of two rails each) are run out as usual. The

line rails are dropped into place. The gage rails are run out 15 ft. further on the rollers of the dollies, then dropped into place and heeled back into the angle bars of the rails already laid. This is done while the line spikers are spiking their first rail, so that no time is lost, as the gage spikers start their work as soon as the gage rail is in position. The pioneer car may have an overhead projecting frame which carries hoisting trolleys equipped with rail tongs. A pair of trolleys takes a rail and runs it out ahead of the car, where it is lowered into place under the guidance of two men.

The organization for laying two miles of track per day on the Chicago, Kansas & Nebraska Ry. was as follows: On the train: 2 bolters, 4 or 6 rail pullers, 1 man throwing rails on rollers and dropping off bolts and spikes, 6 men handling ties and running the tram (or 8 men with two trams); 13 to 17 men in all. In front of the train: 8 spikers, 4 nippers, 12 rail men, 2 bolters, 2 men moving the "dolly," 1 handling the tie line, 1 handling the 30-ft. pole and marking the ties, 1 spike peddler, and 1 water boy; 31 in all. Behind the train: 4 bolters, 12 to 14 men with two track jacks and some picks, pulling in and spacing the additional ties, 16 to 20 spikers, 8 to 10 nippers, 5 liners, 2 spike peddlers, 1 tie marker and 1 water boy, or 49 to 57 in all. The complete crew would consist of 1 general foreman, 1 heeler acting as foreman of the front gang, 1 foreman in charge of the back spikers, 1 foreman of tie gang, 1 subforeman lining track, and 100 to 115 laborers. The tie markers carried a measuring board, which they placed on the line end of every tie, striking a chalk line across (16 ins. from the end of the tie) to guide the spikers in keeping ties in line. With four quick bolters in front, easy-fitting bolts, and a well-trained front gang, a 60-ft. section was often laid in 2½ minutes. Owing to delays in switching and running to and from work, the force never worked 10 hours consecutively, but over two miles of track were usually laid in 9 hours' steady work.

Roberts System.—The flat cars are fitted with runways on each side, these being supported by brackets inserted from the bottom of the stake pockets. The special feature is that the rollers of these runways are driven by power. Each 34-ft. runway has a shaft, with bevel gears to the rollers, and these shafts are connected by universal couplings, while the runways also have flexible connections between the cars. Sectional corrugated rollers are used for the ties. Between these driven rollers are smaller dead rollers whose faces are about 1 in. below the live rollers. In the rail runway, the rollers are double, one for each line of rails. The shafts are driven from an engine on the pioneer car, taking steam from the locomotive. Friction clutches allow of stopping and starting each line of shafting independently of the other. The ties are delivered 60 ft. ahead of the pioneer car, so that they are distributed well in advance of the rails. The rails are delivered 6 ft. ahead of the car, at a height convenient for handling by the rail gang. This arrangement puts the heel joint 8 or 10 ft. ahead of the car. On the front end of the car are the splice bars, bolts and spikes; tools and a few short rails can be carried at the rear end. The tracklaying train is made up with the rail cars in front of the locomotive and the tie cars behind.

In 1905, tracklaying by this system on the Minneapolis, St. Paul & Sault Ste. Marie Ry. averaged 2.1 miles of main track per day, with sidings in addition. The average force was 110 men (130 for a full crew), and could lay 6,500 ft. of track in 3½ hours. The track had 3,000 ties per mile, and was spiked and lined. The system was also used in 1905 on the Chicago, Indiana & Southern

Ry., where the sidings for material were ten miles apart. The track was not full spiked and bolted ahead of the train, but the average progress was about one mile of track per day (full tied, spiked and bolted). Behind the track-laying train was a surfacing gang of about 160 men. The distribution of the tracklaying gang (averaging 100 men) is shown in Table No. 23:

TABLE NO. 23.—TRACKLAYING GANG WITH ROBERTS MACHINE; C., I. & S. RY.

With the Train.		Behind the Train.	
1	Foreman.	2	Foremen.
1	Engineman on pioneer car.	2	Distributing spikes and bolts.
6	Throwing ties into runway.	24	Back spikers.
2	Throwing rails into runway.	12	Back nippers.
1	Distributing splice bars, bolts and spikes ahead.	4	Back strappers.
12	Receiving and placing ties.	6	Spacing and lining ties.
11	Receiving and placing rails.	6	Lining track.
4	Strappers putting on splices.		
2	Tie liners.		
40		56	

Hurley System.—This differs essentially from the other systems described. The pioneer car is self-propelling and can haul a train of 15 supply cars. It resembles a large box car, and is carried on three trucks, each of which is driven by power. Upon it are two engines of 100 HP. Next to this is a car with coal and water. The cars with rails are at the rear of the train, which is the reverse of ordinary practice. A steel truss projects 60 ft. ahead of the pioneer car, and is about 8 ft. above the track. Rails are handled by trolleys on the bottom chords, while ties are handled by a chain conveyor passing over the top chords (which form an incline at the front end). On the floor of each flat car are pairs of flanged rollers, 7 ft. apart transversely, and on the tie cars the ties are supported about 12 ins. above the floor to clear these rollers. The machine hauls forward along the train two continuous strings of rails, by means of a pair of driven rollers between which the rails are gripped. The men on the rail cars drop rails upon the runway rollers, and attach the angle bars by a single bolt to each rail. The rails thus form a conveyor upon which the ties are placed, the proper number to each rail length. On reaching the pioneer car, the ties are delivered to the chain conveyor passing along the top of the cantilever truss. As each rail passes through the driving rolls, it is disconnected at the heel, and is attached to rail tongs on trolleys which run it out ahead of the car. As it is lowered, the loose splice bars at the heel spread to pass over the head of the previous rail and are then temporarily secured by a clamp. The train moves forward while the joint is being completed and the rail quarter spiked. Each side is worked independently, so that the rails can be laid with even or broken joints, as may be required. The cantilever truss is high enough from the ground to clear the men, and it can be swung on curves to deliver the material at the proper position on the roadbed. This equipment has been used on several roads, and has handled 100-lb. rails on the Bessemer & Lake Erie Ry. About 2½ miles can be laid in a 10-hour day with a gang of 40 competent men.

Westcott System.—The special features of this are the rail-handling device and the rail and tie conveyors operated by power. The pioneer car is a flat car, having at the ends vertical steel frames which support a pair of triangular trusses with horizontal bottom chords. This structure extends as a cantilever

about 20 ft. beyond the car. On each bottom chord run two hoisting trolleys having cables attached to rail tongs. Each truss has two air-cylinders with cables led to the trolleys; one serves to run them forward and the other to pull them back. Along the middle of the car, and projecting about 15 ft. in front of it, is a conveyor for delivering the ties at the head of the machine. Behind the tracklayer car are cars with rails sufficient for about 1,000 ft. of track, and having a conveyor (above the floor) which extends to the pioneer car. Behind this again are the cars with ties which are fitted with a conveyor extending under the rail conveyor and beyond it in front of the machine. Behind the tie cars and next to the locomotive is a car carrying supplies and having a steam engine which operates the conveyors. The movements of the trolleys and conveyors are controlled by a man stationed above the pioneer car.

Two rails are run out and lowered into position upon the ties. They are then bolted at the heel joints and temporarily connected with bridle bars to hold them to gage. The train then moves ahead, and as soon as it comes to a stop the conveyor is started, delivering the ties already in the trough. While the train is moving ahead and the ties are being distributed, the rail trolleys are run back and their tongs are attached to another pair of rails on the conveyor at the middle of the car. These are then swung to the sides and run out ahead of the machine, ready to be lowered in place as soon as the ties are laid. The spiking gang follows the tracklaying train, and spikes the rails while the ties are being distributed. This machine was used on the Pacific Traction Co.'s electric interurban line at Tacoma, Wash. The rails were 33 ft. long, and from 2 to 2½ miles per day could be laid with the following force: 1 foreman, 4 men to operate the machine and feed ties and rails, 6 men to distribute and space ties, 4 strappers, 8 spikers, 4 nippers, and 1 spike peddler.

A combination method of working, in which the ties were distributed by teams and the rails were handled by runways and the pioneer car, has been used by the Canadian Northern Ry. The tracklaying train consisted of the pioneer car at the head, then the flat cars of rails, and then the engine; behind this were the cars of ties and bridge material. The full number of ties were laid ahead of the train, and the rails were spiked at joints, quarters and centers. The bolting and spiking were completed close to the rear of the train. The pioneer car had an elevated platform or cabin for a man with a flag to signal the engineman when to move ahead as each rail length of track was laid. The rails were run to the front in roller-ways or chutes attached to the sides of the flat cars. These chutes were about 30 ft. long, composed of two timbers 3×8 ins., 16 ins. apart, held together by bolts with spacing sleeves; journaled in the side timbers were 4-in. rollers (having collars on the ends), about 3 ft. apart. The ties were hauled ahead of the train by teams, about 50 teams being employed. These averaged 25 ties each, but the number varied, depending upon the nature of the ground over which they had to be hauled. The sidings for material trains were about 7 miles apart. The boarding train consisted of sleeping and dining cars, timekeeper's car with stores, supply cars, and a car for the general foreman. Double-deck sleeping cars were used on some of these trains. All bridge material (piles, posts, caps, stringers, etc.) was kept on the rear of the tracklaying train and hauled ahead by teams to the various structures. The timber was erected by bridge gangs ahead of the track, and the tracklaying train crossed the bridges when laid with half the complement of stringers and common track ties. The addi-

tional stringers, the proper bridge ties (12 ft. long), and the guard rails, were placed by a gang in the rear of the tracklaying gang.

The tracklaying gang was exceptionally large, averaging about 240 men, and worked from 7 a.m. to 6 p.m. It laid an average of 2.25 miles per day, or 17 miles per week, the maximum record being 3.7 miles in one day. Three (and sometimes four) gangs followed the tracklayers, surfacing and lining the track; each of these gangs consisted of 80 to 100 men. The distribution of men in the tracklaying gangs for laying 3½ miles of track per day is given in Table No. 24. The extra men to lay sidings and to finish work behind the tracklaying gang proper bring the full force up to about 240 men.

TABLE NO. 24.—TRACKLAYING GANG; CANADIAN NORTHERN RY.

In Front of Engine.		In Rear of Engine.	
1	Foreman.	1	Foreman.
8	Rail pullers.	24	Spikers.
2	Line men.	12	Bolters.
14	Tie men.	6	Nippers.
4	Spikers.	3	Spike distributors.
2	Nippers.	1	Putting in bolts.
18	Steel men (handling rails on both sides of car).	1	Water boy.
1	Liner.	6	Liners.
1	Gage man.	6	Tie men.
1	Tie marker.	80	Men handling ties, including teamsters.
4	Bolters.	1	Blacksmith.
4	Loading steel on trams.	2	Cooks.
		4	Helpers.
		1	Timekeeper and storekeeper.
60	Total.	148	Total.

CHAPTER 19.—BALLASTING AND RENEWING RAILS.

Ballasting.

The ballasting of track is a work which has to be done both as construction and maintenance work. In the latter case it is required for increasing the quantity and improving the quality of the original ballasting. In constructing the track for a new line, the ties are first laid upon the subgrade, and when the rails have been laid earth is tamped under the ties and the track is lined and surfaced to make it safe for the ballast trains. When the ballast is deposited the track is raised by jacks and the material filled in beneath the ties. In some cases, however, the track is jacked and blocked up above the subgrade before the ballast is distributed. For stone ballast, the ties may be blocked up 4 to 6 ins. with spalls or flat stones; the ballast train is then run upon the track, and the material filled and tamped under the ties. This will suffice to carry the construction traffic, after which the track is raised for another filling of 4 to 8 ins. to give the standard depth of ballast. Whether the track is raised before or after the ballast is deposited, it is liable to injury by traffic, causing vertical kinks in the rails and at the joints. For this reason, as little traffic as possible should be run over a half-tied and unballasted track, but this is often neglected in actual work. The English practice is to use a temporary track of old rails for the construction trains and ballast trains. When the track is properly ballasted the regular rails are then laid for the permanent track. This is the origin of the term "permanent way" as applied to track. It is not intended to indicate (as is often assumed in this country) that the

track itself is permanent, but to distinguish the regular or "permanent" track from the temporary construction track.

Grade or ballast stakes are set generally for the level of top of rail. These are set on both sides of the track, about 5 ft. from the center line, or 4 ft. from the rail on one side only. Their location should be governed by the question of avoiding disturbance by the dumping of the ballast. This will differ a little according to the style of cars and unloading of ballast; and (on double track) according to whether one of the two tracks is an old track where no change is to be made and where a grade stake for top of track can be set safely without fear of its being disturbed. The stakes are set at all points where changes of grade occur. They are also set at intervals of 100 ft. on tangents and 50 ft. on curves, giving the proper elevation* for curves. On curves, the stakes are usually set for the inner or lower rail, this rail being kept at grade and the superelevation put entirely in the outer rail. On roads using spiral transition curves, grade stakes are also set opposite the P.C. and P.T. and at each change point of the spiral. Large stakes or posts are sometimes set clear of the roadbed at these points and at the beginning and end of curves. At grade intersections where vertical curves are used, the stakes are set for the proper profile. A red chalk mark should be made on top of every grade stake whose top is intended to be the exact top of rail level. Otherwise the stake should be distinctly marked to indicate the distance above or below top of stake for grade. These stakes should not be set until they are needed, as if set ahead of the tracklayers they are pretty sure to be disturbed. No care is required in securing an exact distance from center line; in fact, if they are set in an irregular line, inexperienced men are less likely to mistake them for center-line stakes.

The ballast should not be distributed until the banks are properly completed and the roadbed is finished to the standard cross section, so that the material will not be mixed with the earth and clay of the roadbed. If the stakes show too little or too great a depth, the roadbed should be trimmed or filled accordingly. In ballasting, all earth above the bottom of ties should be removed; and in reballasting, all old and dirty material between the ties should be removed. Old broken-stone ballast may be shoveled out and then handled and put back with forks, thus freeing it from dirt. Where a good supply of gravel is available, it will be found economical to have gravel trains at work to keep the track well ballasted, as this will tend to reduce the maintenance work in wet weather, or in winter when the frost is in the ground. On the other hand, it must be recognized that ballast is usually somewhat expensive, and should not be used for filling sags or for other work where cheaper material would suffice. The minimum depth of ballast under the ties should be 8 ins. or 12 ins. for first-class track. The cost of ballasting with 6 ins. of gravel below the ties has been estimated at $580 per mile of single track, of which $320 is for delivering the gravel and $200 for putting it in the track. This is based on 30 miles average haul; $15.11 per day for engine, train and crew, and 11 cts. per hour for labor. The cost of train includes engineman, fireman, flagman and conductor; the latter acts as foreman of the gang. The work may be done in the spring, before tie renewals are made, so that when the ties are renewed and tamped the track is left in finished condition.

The ballast is generally loaded onto the cars by a steam shovel. A conveyor may be used, fed by a shoveling gang, and the men's scoops may be suspended from an overhead frame so they do not have to lift each load in taking it from

the bank to the conveyor boot. Ballast is sometimes carried on flat cars with low hinged sides, or sides of loose boards supported by short stakes in the stake pockets. On important work, however, gondola cars are more generally used, whether for depositing the load by hand shoveling, plowing or dumping. Several roads use such cars 40 ft. long, of 32 cu. yds. capacity (50 tons nominal load capacity), with sides 3 ft. high. Each side is formed by a series of doors hinged at the top and locked by cams on a shaft running along the sill. When the doors are released by turning the shaft, the material can be shoveled or plowed out through the sides. A flat car 33 ft. long and 9 ft. wide can be loaded with 10 to 12 cu. yds. of ballast, or 14 to 15 cu. yds. if 12-in. side boards are used. Hand shoveling for unloading is slow and expensive, unless for small pieces of work or where small quantities have to be thrown off various points. It is sometimes preferred, however, on extensive work for additional tracks (where the ballast trains do not block traffic) and for reballasting; in such cases, the same gangs unload the trains and then put the ballast under the ties. To avoid surface bending of the rails by trains running over loosely ballasted track, the ballast of each train load should be thoroughly tamped as soon as it is put into the track.

Ballast is more generally unloaded by plowing or dumping. In the former case, the cars must be connected by iron aprons to prevent material falling on the rails, and gondola cars must have the end gates removed. The side boards must be removed from flat cars, and the side doors of gondolas released. On the rear car of the train is a heavily weighted wedge-shaped plow, extending the full width of the car, and shaped to throw the material off on one or both sides. It is guided by side stakes on the cars. To the nose of the plow is attached a steel cable extending over the cars, and led through pulleys or snatch blocks on chains attached to the sides of the cars if the unloading is to be done on a curve. If the plowing is done by the locomotive, the train is stopped at the place where the ballast is to be unloaded, and the car brakes are set. The cable is attached to the locomotive, which is uncoupled, and moves slowly ahead, hauling the plow along the cars. With loose gravel, the engine can be run at about 4 to 6 miles per hour. When the plow has been drawn the length of the train, the cable is unhooked and thrown to the side of the track. The end may be hitched to a stand resembling a mail crane. As the next train runs slowly by, the end of the cable is attached to the locomotive and the stand lays it in position along the cars. The cable is thus handled by one man, while in ordinary practice it takes several men a considerable time to place the heavy steel cable on the cars.

When plowing ballast in this way, the entire train load must be deposited at one place. A more convenient arrangement, however, is to use a "rapid unloader," in which the cable is operated by a winding engine mounted on a car next to the locomotive, steam being supplied from the locomotive or from a boiler on the car. With a train made up in this way the material may be dumped in one place or at several places; or any desired quantity can be unloaded and distributed by the locomotive moving the train ahead while the plow is being hauled along the train. The locomotives of ballast trains (and work trains generally) should be kept equipped with jacks and wrecking frogs. Derailments are liable to occur, and if these devices are not at hand much valuable time may be lost and traffic perhaps blocked.

Various forms of dump cars are used in ballasting and filling, and should

allow of regulating the quantity dumped. The Rodger cars are 34 or 40 ft. long, of 30 to 50 cu. yds. capacity (40 to 50 tons nominal load capacity). The bottom forms a longitudinal hopper, with doors to deliver the ballast in the middle of the track. The hopper doors are opened to any desired width (up to 22 ins.) by levers at the ends of the cars, the quantity delivered per yard of track being governed by the speed of the train and the width of hopper opening. Under the rear car is a steel plow which can be raised or lowered and rides on the rails when in use. As the train moves, the ballast between the rails is plowed down between the ties and out over the rails (the rails being cleared by flangers), so that it is ready to be put under the ties as soon as the track is raised by jacks. The train can be run at the rate of 3 to 5 miles per hour while delivering the ballast. The Pratt cars used on the New York, New Haven & Hartford Ry. are of 25 cu. yds. capacity. They are 28 ft. long inside, and weigh about 25,000 lbs. empty. The sides are made in two parts, divided horizontally. When the train stops, the upper half of the side of the car is swung down, and half the load dumped. The train then moves on a train length and the lower half of the side is swung up, dumping the rest of the load. In the Goodwin steel cars, only the top 18 ins. of the side is fixed; doors inclined inward form the lower part, resting on a movable bottom piece at the center of the car. Inclined aprons extend over the wheels. The cars have a capacity of 28 to 30 cu. yds., and can be dumped by hand or by air, while the train is moving at 5 to 8 miles an hour. The material is deposited on either side or both sides or between the rails.

The Louisville & Nashville Ry. handles slag ballast in 22-yd. hopper-bottom center-dump cars of its own design. Each car has at the front end a tie or plow laid across the rails, instead of leveling off the whole train load by a plow at the rear of the train. Many roads haul ballast, cinders, etc., in cars having the bottom sloped from the middle to each side, the material sliding out as soon as the sides are removed or released. As ballast trains are expensive and cause delay to regular trains, the plan is sometimes adopted of delivering small quantities for repair work by means of dump cars hauled in local freight trains. For such work the Michigan Central Ry. uses special cars of 25 to 30 cu. yds. capacity; the bottom slopes steeply to each side, and two transverse bulkheads form six pockets or compartments. Each pocket has a swinging door at the side of the car, and a swinging board half way up the slope, subdividing the pocket. Thus a large or small amount of ballast can be dumped at any point, as desired. A few of these cars are put together in a freight train, and stopped at the required spot (marked by stakes). The trainmen release the outer doors, the amount of ballast being sufficient for a raise of 6 to 8 ins. in the length of the car. The train then moves on, and the inner doors are released, depositing the same amount of material beyond the first lot. A similar plan is used by the Delaware & Hudson Ry., but the cars are set out of the freight trains at specified points and then taken by work-train engines.

In all cases where ballast is deposited between the rails, care must be taken to control the flow, otherwise the ballast may flood the track, covering the rails and blocking the wheels so as to stall the train. The bottom doors cannot then be closed, and as fast as the material is dug out from the side it will flow in until the cars are empty. Ballast deposited outside the rails must be kept clear of engine cylinders and car steps. Ballast trains with 22-yd. center-dump cars on the Louisville & Nashville Ry. average 15 cars each, with a foreman

and six shovelers in addition to the train crew. On the Chicago, Rock Island & Pacific Ry., trains with 15 to 25 center-dump 30-yd. cars were handled by a conductor and two or three brakemen; no sectionmen or extra men were on the train. On the Delaware & Hudson Ry. four men operated a train of center-dump cars, while three operated a train of 20 flat cars (10 yds. per car) with rapid-unloader plow; one man operated the plow engine and two handled the cable and snatch blocks. With freely running material, a 30-yd. car load deposited at a speed of 3 to 4 miles an hour will suffice for a raise of 4 to 6 ins. For new track, the Chicago & Eastern Illinois Ry. has made one run with cars dumping at the middle, and a second run with the same cars dumping at one side. For reballasting, the Lake Shore & Michigan Southern Ry. used 25-car trains of washed gravel, with 50 men per train to dig out the old and put in the new ballast.

When the ballast is distributed, the track is raised by jacks (both sides at once) for a distance of about 100 ft., and properly lined. The ballast is then thrown between the rails and tamped under the ties. Two lifts are usually made, and the inclined parts approaching the raised portion must be made solid enough to prevent injury to the rails and joints by passing trains. The shoveling of the ballast from the sides to the middle of the track may be avoided by the use of center-dump cars, as mentioned above. When earth ballast is to be replaced with gravel, the earth between the ties is first dug out. A train load of gravel (giving about 15 cu. yds. per car length) is deposited, and is packed down to make room for another load, filling it in level with the tops of the ties. The track is then raised by jacks, and the gravel shoveled under the ties, after which another load of ballast is deposited. The track is then again raised, the ties are spaced properly, the final tamping done, the track lined and surfaced, and the ballast finally dressed to the required cross section. Newly ballasted track will not long remain in good surface, the material settling unevenly. The section foremen must therefore keep close watch of it, going over it every few days to fill and tamp low spots.

Ballast for new parallel tracks may be deposited at the side of the existing track, and thrown into place by a spreader car at the rear of the train. This has an adjustable wing hinged to a frame at the side of the car, and will spread and level the material to a width of 15 to 20 ft., on one or both sides. The car is usually a heavy flat car with a gallows frame or side posts, from which run stays to the outer end of the hinged spreader or wing, which is 20 ft. to 30 ft. long, built of plank and faced with iron. Adjustable braces are fitted between the wing and the sills of the car, and it can be raised and lowered or adjusted as to position by chains or air cylinders. When not in use, the wings are raised and folded back against the side of the car. In building the additional tracks for the four-tracking of the New York, New Haven & Hartford Ry., a temporary track of old material was first laid on the subgrade. The stone ballast was then deposited, the temporary track being raised by jacks to the proper grade. The permanent track was then laid, and thoroughly tamped, surfaced and lined. The ballast was carried on 10-yd. drop-side flat cars, and unloaded by hand. From this first new track the ballast for the two adjoining tracks was then unloaded, and spread to the level of the bottom of the ties. On the bed thus prepared the new tracks were laid, and were at once ready for slow trains. It will readily be seen how the ballast may be distributed and leveled for any number of parallel tracks after the first track has been laid. With

movable pieces or mold boards attached to the bottom of the wing, the ballast can be trimmed to the required cross section, and ditches can be cleaned. (See "Ditching.") The machine can also be used in clearing snow.

Renewing Rails.

This work should be done from late in the spring to early in the autumn. It is often done at whatever time the new rails can be obtained, even in winter, but this is bad practice. The adzing and trimming of ties for the new rails should be done in advance. The laying of rails should be done under the supervision of the division engineer (or his assistant) and the roadmaster. The superintendent should be informed, in order that train dispatchers may be notified and handle traffic accordingly. Where the traffic is heavy, a telegraph operator should be with the work to keep the foreman informed as to train movements and delayed trains. On the Atchison, Topeka & Santa Fé Ry. a portable telephone equipment is used, hooking upon the wires, to enable the foreman to keep in touch with the nearest operators. Flagmen should be sent out, and in some cases every train is required to come to a stop and then pull slowly over the work. This is not generally considered necessary, as it may tend to block traffic. It is also liable to cause trouble from couplers parting when heavy trains start after being stopped. The work should be done as rapidly as is consistent with good work, but safety and good work are of more importance than speed. Special care must be given to the expansion spacing at joints, the spacing being given by L-shaped iron shims of thickness suitable to the temperature. (See "Rails.") Each shim may be marked with its thickness and the range of temperature for which it is to be used, and the foremen should be provided with thermometers. On the Eastern Ry. of France, the width of spacing is governed by the temperature of the rail instead of that of the atmosphere, and a special form of thermometer is used. The width is obtained by a formula in which A is the expansion spacing (millimeters), B is the maximum temperature which the rails can attain in summer (generally taken as 40° C.), C is the temperature of the rail when laid (degrees centigrade), and D is the length of rail (meters): $A = (B - C)\ 0.0122D$.

In laying new rails on a section there are two principal methods of practice. One method is to lay the new rails along the ends of the ties, to fully bolt up the joints, and then to take up the old rails and throw in the string of new rails. The other method is to lay in one rail at a time. There is also a compromise method, by which the rails are bolted together in lengths of five or six, the intermediate joints being left open, to be bolted up when the rails are in the track. The details of the work and the distribution of the men depend largely upon the traffic, and vary considerably on different roads. Somewhat different methods may be followed where the track can be given up to the roadway department (either on single-track or double-track roads) for a certain time by arrangement with the superintendent or train dispatcher. The method of working on double track on the Boston & Albany Ry. is as follows: The rails unloaded from the work train are placed along the ends of the ties by the section men, all being placed with the brand outside. Care is taken to set the joints correctly, and to use occasional 28-ft. rails on the inside of curves to maintain the proper relation of the joints. The rails are then bent for the curves, and, if necessary, straightened for the tangents, it being found that from 20% to 50% of the rails require to be straightened. The splice

bars, bolts, nuts and spikes are properly distributed, and the ties are adzed as far as possible at the rail seats. If tie-plates are used, this work will be greatly reduced, but if the new rails have a different width of base from the old ones, necessitating the removal and replacing of the plates, then new seats should be adzed for the tie-plates. A large force of men is now employed to cover the greatest length of one track that can be dealt with at one time, this track being closed to traffic meanwhile. From 3 to 5 miles is a fair day's work, varying with the number of switches, but 8 and 10 miles have been relayed in a day of 10 hours.

With a force of 200 men, three gangs of 12 men each pull all the spikes except those on the inside of the right-hand rail. Men with ordinary clawbars start the spikes, others have goose-neck clawbars to pull them out. Then come the men who throw the old rails with crowbars; there are 3 or 4 men to each line of rails, the joints being unbroken except at long intervals. These are followed by 20 or 30 men who finish the work of adzing the rail seats, while 3 or 4 men of this gang have brooms to sweep chips and dirt off the ties. To remove old tie-plates and adze the rail seats where necessary will require about the same number of men as where no tie-plates are used. Then come the two setting-in gangs, 16 on each side, the 16 men lifting one 95-lb. rail with tongs and dropping it in place on the ties, while the foreman puts in iron spacing shims of the required thickness. Sometimes the rails are bolted up in pairs, in which case there are 32 men to each line of rails. These are followed by the strappers, who put on the splice bars, and bolt up each joint fully and tightly. The number of men in this gang will depend upon how well the nuts fit the bolts. If the nuts can be brought to a bearing on the splice bars with the fingers, 20 men will be sufficient, but if a wrench must be used to screw the nut all the way on, 40 men may be necessary. After them comes the spiking gang of 30 men; these work in groups of three, one man having a lining bar and the others having spike mauls. The leading group works on the right-hand rail, forcing the rail home against the old inside spikes, and driving the new outside spikes. The other gangs, or "gagers," have each a track gage, and set and spike the left-hand rails to the proper gage. They also shift any ties that may have been misplaced, and tamp those which do not give a full bearing to the rail. The whole series of operations occupies about half an hour. A separate gang under its own foreman puts in the switches. The work train follows the men, its crew picking up stray tools or supplies and seeing that the track is in safe and proper condition. When the work is complete, the track is again thrown open to traffic. After this, the section men unbolt the joints of the old rail, put the splice bars and bolts together, and throw the rails between the tracks ready for loading. The ties are also respaced as required, more or less of this work being always necessary; tie-plates are put on if required, and the track gaged and respiked. It is then surfaced and finally lined. As soon as the track has been laid by the relaying gangs, the rails are drilled for the bond wires of the signal system, and the creeper plates are put on.

Laying Rails in Strings.—This method is not extensively used, and mainly where the traffic is only moderately heavy. All the preliminary work, and the bolting up of the new rails laid on the ends of the ties, is done while the traffic is passing. The rails are then thrown into place in strings as long as the intervals between trains will permit. One objection is the difficulty of insuring uniform expansion spacing, and much time is apt to be lost in

properly connecting up with the old rail and adjusting the expansion spacing of the string of rails when in position. On curves the new rails may be laid 12 ins. from the old rails. Those for the outside of the curve are given more and those for the inside less expansion spacing than on tangents, at the rate of ¼-in. per 100 ft. length (that is for four joints) per degree of curve. The bolts should also be left somewhat slack, and the expansion spacing regulated and bolts tightened as soon as the rails are thrown into position. The joints between tangent and curve rails should be left open. The spacing may be preserved from change during the work by having all joint ties in proper position and driving the spikes in the slots or at the ends of the angle bars as fast as each joint is reached. Usually only one line of rails is laid at a time, but both may be laid together if desired, one gang being 10 to 15 rail lengths ahead of the other, so as to avoid interference. In any case, the second line of rails should be laid as soon as possible after the first. Care should be taken to avoid bending the splice bars by hurriedly throwing the string of new rails into position with bars. The iron expansion shims are put in when the strings of rails are bolted up, and are left until the rails are thrown into position. Two men may then remove them, one raising the joint with a bar to enable the other to take out the shim. Accurate work can be done with proper care, but it is generally considered that better results and more uniform joint spacing can be obtained by laying rails singly.

At the heel or first connection of the string, a spike is driven to keep the rails from being forced backward. The head connections may not fit closely, however, owing to variations in expansion and to slight variations in length of old and new rails. For this reason it is sometimes necessary to move a string of rails endways. A string of 20 to 50 rails can be removed by from 4 to 8 men with bars placed at intervals of about 6 rails. They place the bars so as to get a bearing against the ends of the angle bars and pull together at a signal. If a work engine is available, a string of rails can be moved by a rope or chain. The foreman should arrange with the train dispatcher to perform the work at times when it will least interfere with the movement of trains. He should then lay the longest stretch that can be properly taken care of in the time available, and have the track finished up before the next train is due. The work should not be done hurriedly.

Laying Single Rails.—The most general practice, especially where the traffic is heavy, is to lay a rail at a time, keeping the track all finished up behind the gang. This method requires a larger gang, as several men are required to lift and move single rails, while two or four men with bars can easily shift a string of rails. The men in the larger gang also work somewhat at a disadvantage by being more crowded. There is the advantage that every interval between trains can be utilized, but if the traffic is exceptionally heavy, much time may be lost in disconnecting and connecting up for each move. A flagman (or two flagmen on single track) must be kept out all the time, while under the former method this is required only when the string of rails is being thrown in.

The practice on the Lake Shore & Michigan Southern Ry. is to lay single rails, and before this is commenced the ties are carefully adzed, bad spikes are removed and old broken spike stubs are driven down. A gang of 54 to 56 men is employed. In advance are 8 men pulling spikes, and when the spikes are drawn and holes plugged, 2 men push out the old 30-ft. 80-lb. rail. With new 33-ft. 100-lb. rails there are 18 men with rail tongs to set the rail in place;

12 to 14 men putting on splice bars and tightening bolts, 2 men with splice clamps forcing the new splice bars into place, and 12 men finishing up the spiking. As a rule both sides of the track are done at the same time. The work advances rapidly, and 4,000 to 5,000 ft. of track per day can be done. Immediately after the rails are laid, an extra gang puts in what new ties are necessary, spaces them to fit the new joints, and gages the new rails. Behind this gang comes the regular section gang to do the surfacing and lining; this work is kept close to the extra or tie gang, so that each day's work is finished as completely as possible. On the Chicago, Burlington & Quincy Ry. the work is done in much the same way, but with a gang of 65 to 85 men, and laying from 50 to 85 ft. per man per day, according to conditions and number of trains.

The practice on the New York, New Haven & Hartford Ry., with new and old rails of 100 lbs. per yd., is as follows: When new rails are received at the yards, they are distributed by work trains, unloaded carefully and placed with the brand on the outside. A gang then places them in convenient position to be laid in the track. Another gang adzes the ties so that spikes may be pulled easily, and the ties are adzed to a level after the old rail is thrown in. When the new rails are to be placed, all the spikes are pulled from the inside of the rail, and the old rail is thrown in. All spike holes are plugged, the rail seats leveled, and new rails placed in position one at a time. As soon as the rail is dropped in place, allowing the necessary expansion, the next gang puts in the bolts and does the spiking. The old rails, when thrown in and unbolted, are picked up by the work train, and stored or distributed at such points as may be specified. A good gang will be composed of 80 men, as follows: 20 pulling spikes, 4 throwing in the old rail, 16 adzing or leveling the ties, 12 placing the new rail, 12 bolting, 8 spiking, and 8 finishing up in the rear. Such a gang with a foreman and assistant foreman should be able to lay about two miles of track per day when it has only an occasional train to interfere with the work.

For still larger gangs, laying one mile of track per day with 85-lb. rails, the organization on the Chicago, Milwaukee & St. Paul Ry. is about as follows: 1 foreman, 5 assistant foremen (1 for spike pulling and adzing, 1 for spiking and bolting, 1 for distributing and picking up, 2 for tie spacing), 1 timekeeper, 12 men unloading and loading, 2 (ahead) putting on splice bars, 14 pulling spikes (2 with mauls), 2 throwing out old rail with lining bars, 1 cleaning ties with broom, 12 adzing ties, 12 with rail tongs, 7 bolting, 18 spiking, 3 holding ties with bars for spikers, 1 distributing bolts, 1 with expansion shims, 68 spacing ties, 1 with push car for joints and fastenings for closing up connections, 2 flagging, 2 water boys; total, 158. Gangs of over 50 men should have a foreman, two (or more) assistant foremen, and a timekeeper. As to relaying with long rails, the Norfolk & Western Ry. has found it possible to lay 1,500 to 3,000 ft. of track per day with 60-ft. 85-lb. rails, without interruption to a heavy traffic. The force consisted of 10 men pulling spikes and throwing out old rails, 16 men putting in new rails, 4 men putting in joints, and 4 or 6 men spiking joints, centers and quarters. There was no appreciable difference in speed between the laying of 60-ft. and 30-ft. rails. The joints had outside angle bars and 8-in. inside fish plates with two holes, so that no inside spikes had to be drawn. Afterwards the Churchill joint was applied.

Relaying rails where trains pass every few minutes is close work, which is necessary on rapid-transit railways. On the New York Elevated Ry. (electric) a gang of 18 to 20 men can renew a rail in 1½ to 2 minutes; this includes

cutting out bonds, renewing spikes, loosening joints, removing rail, setting new rail, spiking, bolting up joints and rebonding. On tangents the work is done between 10 a.m. and 3 p.m., with trains at intervals of 2½ minutes; in this time 60 rails can be renewed without interfering with traffic. On the subway lines of this system, work is done between 1 a.m. and 5 a.m.; with trains at intervals of 7½ minutes on the local tracks, 33 rails can be renewed; 64 rails can be renewed on the express tracks, which have no trains between these hours. A caution flag or light is set 500 ft. from the work, and a man with a red flag (or lamp) is placed within communicating distance from the gang. On the Boston Elevated Ry. (electric) all the relaying is done between 1 and 5 a.m.; from 30 to 50 men are employed, but may be divided into three or more gangs under subforemen. During the day, a gang of 8 men is employed in curving and otherwise preparing rails. A broken rail (with an insulated joint at one end) has been removed and placed in 12 minutes. On the South Side Elevated Ry. (Chicago), this work is done early on Sunday morning, traffic being temporarily operated on single track. On curves of 100 ft. to 200 ft. radius, 20 men can relay 10 or 15 rails in from 3 to 4 hours; and also load the old rails. On straight track, 35 men can relay about 60 rails in 6 hours, the rails being previously bolted up and bonded in sections of 10 rails each. This time includes the placing of new tie-plates. Screw spikes are used, but are placed only for every third tie when rails are being laid. The others are put in later, under traffic.

If the new rails have the same width of base and head as the old ones, all the outside spikes may be removed, the inner spikes being loosened, so that the old rails can be lifted out and the new ones slipped in against the spikes. As there is generally some difference in the rails, however, due to a variation in section or to the wear of the old rails, the outside spikes may be drawn on one side of the track and the inside spikes on the other side, so that the new rails can be spiked to gage. Three rows of spikes may also be drawn for this purpose. Where the new and old rails meet, care should be taken that the heads are in the same line, gage and level. For small differences, an iron shim under the lower rail may be used, but for larger differences, a special joint is required. Where the new rails are heavier than those of sidetracks, they should be laid on the turnout and extending beyond the frog, so that the special joint will not come upon the switch ties. The rails must not be punched, nicked or slotted, as such marks are liable to cause fracture, but all holes made in the field should be drilled. Short rails are only admissible on the inside of curves or as a temporary expedient on tangents, and no rail shorter than 15 ft. should be used in main track. For details as to cutting and bending rails, etc., see "Maintenance."

On curves, it is necessary to use a short rail at intervals in order to keep the joints from overrunning, 26-ft. and 28-ft. rails being frequently used. The total difference in length (in feet and decimals) of the inside and outside rails of the curve may be obtained by multiplying the constant 0.08552 by the number of degrees in the central angle of the curve (the minutes being either disregarded or reduced to a decimal of a foot). This total must be distributed over a suitable number of rails so as to avoid the use of one very short rail, and also to keep the joints as even as possible. A 30-ft. rail may be cut into two parts, differing in length by the difference ascertained as above. Then by laying the longer piece at the beginning of the outside line of rail and the

shorter piece at the end of the inner line of rail, these will give broken joints on the curve and square joints at the ends. Another method is to allow a difference of 1.03125 ins. in length per 100 ft. for each degree of curve; or, in other words, to multiply 1.03125 ins. by the degree of curve and the number of hundreds of feet in the length of the curve. Methods of finding the degree of a curve in the track are given under "Lining." To change from even joints or tangents to broken joints on curves, the length of short rail on the inside may be found by measuring from the center of the rail ½-in. for each degree of central angle of the curve. Table No. 25 shows the difference in length of outside and inside rails for lengths of 100 ft. on various curves.

TABLE NO. 25.—DIFFERENCE IN LENGTH OF OUTSIDE AND INSIDE RAILS ON CURVES.

Degree of curve.	Difference for 100 ft. in ins.	Degree of curve.	Difference for 100 ft. in ins.	Degree of curve.	Difference for 100 ft. in ins.
0° 15′	.2465	3° 0′	2.9583	7° 0′	6.9027
0° 30′	.4930	3° 30′	3.4513	8° 0′	7.8888
0° 45′	.7396	4° 0′	3.9444	9° 0′	8.8749
1° 0′	.9861	4° 30′	4.4374	10° 0′	9.8611
1° 30′	1.4791	5° 0′	4.9305	11° 0′	10.8471
2° 0′	1.9722	5° 30′	5.4235	12° 0′	11.8333
2° 30′	2.4652	6° 0′	5.9166		

Example: 3° 30′ curve 615 ft. long. $3.4513 \times 6.15 = 21.25$ ins. $= 21\frac{1}{4}$ ins.

It is usually required that the rails must all be laid with the maker's brand on the outside (sometimes the inside) of the track. This is to provide for possible defects in the rolls by which the sides of the head may be slightly unsymmetrical. Rails of similar section should be kept together, and this is specially to be observed in distributing old rails for relaying on third track, branch lines, etc. With old rails, this rule should not be observed where it will put a badly worn gage side against a uniformly worn gage side of an adjacent rail. Old rails for relaying should be sorted for height at the yards, and sent out in lots of the same height. They should be laid with the unworn side of the heads as the gage side.

In temporarily connecting the new rails with the old to allow a train to pass, a 15-ft. switch rail should be used, being firmly spiked to place and having its surface slightly above that of the stock rail against which it is laid, in order to carry tires that are worn hollow. If this plan is followed in closing up work for the night, great care must be taken to properly set and secure the rail, and it should be clamped to the stock rail to prevent being thrown out by a trailing movement. On many roads it is preferred to connect up the track at night with pieces of regular rails and full-bolted splice joints. The short rails and taper rails for these connections, with the necessary fastenings and tools, may be kept on a push car ahead of the rail gang and in charge of one man, so that the material will be promptly available when needed. No train should be allowed to pass unless each rail has at least 4 inside and 6 outside spikes (or half the full number of spikes on curves), and each joint has at least the two middle bolts in place and properly secured. After the new rails are laid, the string of old rails which has been thrown into the middle of the track may be unbolted and taken apart at leisure, all bolts, nuts, nut locks and splice bars being carefully preserved. The old rails should not be left in the ditches, but placed beside the ballast or piled ready for loading onto the cars. Many men believe it is necessary to renew rails on Sundays on account of the traffic.

The work can be done, and is done, as well on week days, and (as already noted) Sunday should not be made an extra work day.

Handling Rails.

In renewing rails, a common cause of complaint is the number of kinked and surface-bent rails, and these are often offered as an excuse for roughly riding track. Such defects may be caused by dropping the rails in unloading them. Rails should not be dropped or thrown from the side of the car upon the roadbed. If this is necessary, care should be taken that they are dropped on soft, level places, and that they do not strike ties, boulders or other rails. The rails should not be allowed to slide off the cars and drop upon the ties. Neither should they be unloaded from a moving train, except where the movement is used to pull the rails from the cars. In throwing off rails, at the first stop of the train two unloading gangs of 8 or more men each may work from the ends of the train, throwing two rails off each car. When they meet at the middle car, the train moves ahead one train length, and the gangs work from each other to the end cars. The number of men required varies with the length and weight of the rails. The greater the number, the greater is the liability of injury, and in most cases it will be economical as well as otherwise advantageous to use rail-handling machines and other appliances described below. Rails 30 ft. and 33 ft. long can generally be carried on ordinary gondolas or flat cars, end gates or planks preventing the rails from shifting. They are sometimes carried in box cars. Rails 45 ft. long can be loaded in two groups on three gondolas (with end gates removed) or flat cars, the middle car supporting the projecting ends of both groups. Rails 60 ft. long may be loaded on two cars, being supported mainly by bolsters just behind the outer trucks, but having intermediate supports over the inner trucks to prevent undue sagging and swaying of the load. The Norfolk & Western Ry. loads 60-ft. rails on alternate flat cars, the ends projecting over the intermediate cars. Three loads (of 34 rails each) require seven cars. Very long cars of special construction are sometimes used in transporting rails from the mills to the railway yards.

If the rails are to be unloaded in piles along the track, for distribution later by push cars, they may be slid down skids from the side of the car, and if the slope is steep they should be controlled by ropes with hooks to fit over the rails. The skids may be two rails, or two timbers about 3×4 ins. (6 to 10 ft. long) faced with iron and having clamps to fit on the car. At the upper end of the skid may be a small pulley (set below the face) for the rope. Two men on the ground lower the rails by these ropes and also shift the skids as the train moves ahead. The rails may also be lowered vertically by means of three or four brackets or straps hooked onto the side of the car, each bracket carrying a horizontal roller at its lower end. The length of the brackets is from 5 to 18 inches. The shortest is at about the middle of the car, and the longest near one end, with the others between them, so that they form an inclined rollerway. Men on the roadbed receive the end of the rail and lower it.

In unloading from the end of a car, the rails may be simply pushed off the car, or hauled off by a rope. Sometimes 6 or 10 men on the car, with tongs, slide the rail off; 8 or 10 men on the track haul the end outside the track until it rests on the ground. Then they move up to the car and take hold of the other end, which they carry out in the same way, laying the rails either upon

the ground or upon the ends of the ties. The men should not be permitted to drop the end of the rail, but there is liability of injury to the men, owing to carelessness or accidental slipping causing them to drop a rail. For hauling the rails off the car, the rope should be 30 to 50 ft. long, with an L hook at one end and a claw hook at the other. The L hook is put through the bolt hole of a rail on the car, and the claw hook placed over the edge of a tie. The train then moves ahead and the rail is thus hauled off. Two men attend to the ropes, and there should be men to lower the free end of the rail.

Rough usage of the rails may be prevented, and the number of men reduced, by using an inclined apron or a pair of trough-shaped skids attached to the end sill of the car and riding on the rails. For gondola cars with fixed ends, a second shorter apron may be attached to the top of the end, its lower end resting on the longer apron. As the rails are hauled off they are supported by the apron until they rest on the ties. In this way, work can proceed quickly with a smaller force and with little danger to the men. Instead of these aprons, the New York Central Ry. couples a small car behind the rail car. This has a triangular incline made of two rails; the upper end (or apex) is level with the floor of the car, and the incline throws the rail to one or other side of the track. A 35-ft. rope is used, with a hook at the front end. The rear end is attached to a 2½-in. round stick 6 ft. long, and is anchored by sticking this into the ballast at the rear side of a tie. Thus the man does not have to stoop, as in operating a tie-hook or rail clamp. A similar arrangement is employed on the Chicago, Milwaukee & St. Paul Ry. There are two 50-ft. ropes, with rail clamps or anchors, one rope for each side of the track. The first rail is adjusted with its end opposite a rail joint; the rope is then anchored, and the train moves forward. About 10 men form the unloading gang; 2 on the car shift the rails into position, 1 on the push car attaches the rope hook and guides the rail to one side or the other as required, 2 men (1 to each rope) hand the hook to the man on the push car, 2 attach and detach the rope clamps.

In loading rails by hand at the yard for distribution, skids may be used, but in loading old rails along the track, the common practice is to have a gang of 25 to 40 men, depending upon the weight of rail and method of handling. With flat cars, the rails are usually raised by main force and thrown upon the car; this is a slow and dangerous process, especially with heavy rails. With box cars or drop-end gondolas, a push car or truck may be coupled to the rear of the train, being kept some little distance from it by a spacing timber. On this truck is a dolly with a roller or a piece of rail at about the height of the floor of the cars. The men pick up a rail, rest one end on the dolly and push this end into the car, where men with tongs pull the rail into place. About 24 to 30 men are required for this, and as each car is loaded it must be set out and the push car again coupled up.

Rail-Handling Machines.

Where there is much work of this kind, it can be done more rapidly and economically than by hand by the use of machines designed for the purpose. For loading and unloading rails on the track and at yards, many railways use derrick cars which can travel along the rail cars, and some of these can also operate on the yard tracks. A crew of from 5 to 7 men with a machine can do the work of a gang of 20 to 40 men. The United machine has a mast and boom giving a clear lift of 14 ft. and a reach of 20 ft. from center of track. Stays

from the mast are hooked to the car sills and tightened by turnbuckles. An air cylinder on the mast, and connected to the brake system, operates the hoisting line, which ends in a chain sling having two rail tongs or hooks. The machine runs on the floor of the car, but may also have grooved wheels to run on the sides of gondola cars with fixed ends. The crew consists of five men, with a foreman: 2 on the car, 2 on the ground, and 1 at the hoist. In some cases a larger crew is used. This machine and crew will do the work of about 20 to 30 men loading rails by hand and at about half the cost. It can load rails along about two miles of track per day, the work depending in part upon traffic conditions. It has been used on the Illinois Central Ry., Chicago & Alton Ry., and several other roads.

The Laas machine used on the Chicago, Milwaukee & St. Paul Ry. is generally similar, but has the tackle blocks and air cylinder (8×72 ins.) on the boom, with an air reservoir on the truck or car. As a rule a single pair of rail tongs on the hoisting line is attached to the middle of the rail. Two men attach the tongs and guide the rail as it swings; two others receive it and place it, and a fifth detaches thé tongs. The foreman (or another man) operates the hoist. The Travis machine used on the Fort Worth & Denver City Ry. has a car with a frame of steel I-beams and mounted on four small wheels. An upper frame, revolving as a turntable, carries at the front end an upright gallows frame, with inclined I-beam braces, and having its top 10 ft. 3 ins. above the rails. At each side of the frame is a mast of 4-in. gas pipe, pivoted at top and bottom, and carrying a 20-ft. boom of 4-in. pipe, the end of which is supported from the head of the mast by a topping lift. The drums for the topping and hoisting lines are operated by a gasoline hoisting engine. The end of the hoisting line has two 4-ft. chains attached to the ends of a stretcher or bar 6 ft. long, from each end of which hangs a chain with rail tongs. When the machine is operated on fixed-end gondola cars, its track is supported by timber horses set on the floor or by timbers laid across the sides.

The Ware machine used on the Buffalo, Rochester & Pittsburg Ry., for unloading rails from gondola cars with fixed ends 4½ ft. high, consists of a gallows frame set across the car, with the uprights seated in portable pockets hooked to the side of the car. From the top bar are suspended two air-hoist cylinders, whose piston rods carry rail tongs. Hooked to the top of the car, at the end are two channel-shaped skids whose lower ends are attached to a crosspiece having small grooved wheels which run on the rails. The crew consists of eight men on the car (four to each side): 2 at the hoists, 2 at the tongs, and 1 at each end of each rail. When the rail is raised it is guided so as to rest on a roller on the inner side of the upright, and another roller at the top of the skid. The tongs are then released, and the rail is easily pushed out until it tips forward and slides down the skid. As the train moves forward, the skids moving under the rails lower them to the track. The loading, unloading and stacking of rails at yards may be conveniently and economically done by regular or special equipment. Locomotive cranes, derrick cars, and wrecking cranes may be utilized, as well as fixed derricks or cranes. They may be equipped with air hoists (having either direct attachment or cables), or with drum hoists operated by steam, gasoline or electric motors.

CHAPTER 20.—DRAINAGE AND DITCHING.

The provision for carrying off the surface drainage of the land traversed by the railway comes more properly under the head of construction or engineering work than of maintenance or track work. The necessity of providing ample waterway at all bridges and culverts is universally recognized, but it is not always observed in practice. In the maintenance work, therefore, the engineer, roadmaster and section foreman should have in mind what culverts or waterways are occasionally found to be of insufficient capacity. Until increased capacity can be obtained, care must be taken that the opening is kept free from drift and obstructions and protected against wash, that no fencing is placed across it, and that the sides of the stream or the slopes of the embankment are protected from wash. This protection may consist of rip-rap of rough quarry stones, brush, cribbing of trees and logs, or trees laid on the slope with the trunks pointing up stream, and the branches weighted down in the water. No fences or wires should be allowed across drainage openings, as these check and collect drift which may block the waterway and cause washouts in time of flood. The foremen should mark flood high-water levels for the future use of the engineer in investigating the necessary capacity of openings. Every opening in the roadbed is to a certain extent a source of danger, and the old style of open culvert is giving way to culverts of iron pipe and box or arch culverts of stone and concrete, covered by the embankment. For methods of calculating the necessary area of waterway at culverts and bridges, see a paper by Mr. Geo. W. Bremner (Chicago, Burlington & Quincy Ry.), Journal of the Western Society of Engineers, April, 1906. Also the Proceedings of the American Railway Engineering Association, 1907 and 1908.

The drainage of ground water from the land is a different problem, which may be very serious in wet soil and on sidehill lines. The methods adopted will depend upon the character of the soil, the geological conditions, and the amount of water to be dealt with. In bad cases, special treatment may be necessary to prevent slides. These cases may be where the cuts are in wet clay, or where the upper body of material rests on a smooth and sloping stratum of rock or hard clay, which not only holds water in the upper body but provides a surface upon which the mass may slide if disturbed. In Europe, these conditions are often investigated very fully before and during construction, and costly works are provided to establish permanent conditions. In this country reliance is apt to be put on more superficial investigation and the adoption of temporary expedients, with consequent high cost and continual trouble in maintenance. The question in each case is how best to remove the water and consolidate the treacherous material. Particulars of work of this kind at both cuts and banks will be found in "Engineering News," Sept. 13, 1906; the "Railroad Gazette," March 11 and Sept. 9, 1904; and the Proceedings of the American Railway Engineering Association, 1907.

Soft spots sometimes appear continually, in cuts or banks, requiring periodical filling and surfacing and the cleaning out of ditches. Such cases should be carefully investigated, as the filling is evidently only a temporary relief, and may make conditions worse. The first thing is to find where the water comes from. and to remove it or provide for its escape. The soft material

may then be dug out. Cinders are generally best for filling, as they will not mix with the clay, like stone or slag. Where a firm material underlies the sliding material, trenches for tile drains may be cut into and through the former. These will then be filled with cinders or gravel. It is not much use to put a tile drain in the wet or sliding material, as the movement of the mass will distort it, throwing it out of line and filling up the drain. If a cut slides in winter or in bad weather, ditching it out will often keep it sliding or make it worse. In such cases, as long as the material does not encroach on the track, it may be best to leave it, and cut cross drains through the ballast to carry the water to the ditch on the other side of the track. On sidehill work, ample provision must be made for carrying off the surface water by culverts, ditches and drains. A ditch near the top of the cut will intercept much water that would otherwise flow down the slope. There should be a good ditch at the foot of the slope of cut, and under this may be a tile drain with laterals extending under the roadbed and discharging on the downhill side. Drainage is of special importance in grade reduction work, and care should be taken to see that deepened cuts are well drained. Tile drains may be used to advantage when such work is done, to supplement the ditches.

The width of subgrade should be increased in wet cuts, to give ample room for ditches. It will also allow of putting the ditches farther from the roadbed, as water will seep into and tend to saturate the latter. In practice the cuts are often made too narrow to allow of proper ditches, and expense is incurred in subsequent widening or in constant maintenance and in cleaning ditches The slopes, also, are often left too steep, increasing the liability of slides or causing a constant falling of surface material into the ditches. If the proper width for slopes and ordinary ditches cannot be obtained, as in cuts through valuable property, masonry retaining walls may be built near the track, and the slopes commenced from the tops of these walls. Ordinary or sheet piling is sometimes necessary in the slopes or at the toes of cuts. In soft cuts deeply gullied by rain, cribs of old ties are sometimes used, but are unsightly and generally of only temporary value. Such cribbing should be higher at the track side, sloping back to the bank, so as to afford greater resistance to displacement, while the edge forms a convenient platform from which to shovel the sliding clay into cars. It has been found in cuts through clay with an overlying stratum of earth, that if the material is excavated to a vertical face at about the middle of where the ordinary slope would be, when the face sloughs off, the earth will cover the clay and protect it from the weather.

Some wet gumbo cuts on the Canadian Pacific Ry. had to be cleaned out and widened with a steam shovel, and then two rows of piles, 8 ft. apart, were driven on each side of the track. Sills laid under the roadbed kept the inner rows from moving, and inclined braces were put between the inner and outer rows. The mud was dug out and coarse gravel filled around and behind the piling, through which gravel the water drained to the track ditches. At the Boone viaduct of the Chicago & Northwestern Ry., a sliding hillside was checked by digging trenches 250 ft. to 350 ft. long. These extended in the direction of the movement, and were from 4 ft. deep at the lower end to 10 ft. at the upper end. They were 5 ft. wide on the bottom, and were filled with 3 ft. of one-man rip-rap and 2 ft. of willow brush, covered with backfilling. A track along the sidehill slope, and subject to continual slides, was made secure by means of surface drains. Wooden box drains were put between the ties

at intervals of 10 or 15 ft., and extended up the slope of the hillside, with occasional diagonal lateral drains leading into them. The best remedy in cases of this kind is to thoroughly investigate the conditions and to provide ample drainage, with ditches of sufficient capacity to carry off the water quickly, and then to provide such auxiliary work as may be necessary.

On the Chicago Division of the Cleveland, Cincinnati, Chicago & St. Louis Ry., trouble has been experienced with the slipping of a wet sidehill cut about 40 ft. deep. The material is a wet yellow clay (standing at about 1 on 1½) on a stratum of shale or hardpan. Water soaking through the clay mass gives a smooth and slippery or lubricated surface to the shale, and upon this the clay slides. The movement was evident nearly ¼-mile from the cut. Near the cut was a public highway, and this was only kept passable by filling in from the top as the earth slipped towards the cut. The road was about 75 ft. out of line. Two rows of piles were driven along the lower side of the original line of the road, and two rows of piles were also driven at the toe of the slope. The rows were 4 ft. apart, and the piles also 4 ft. apart, the rows being staggered. The piles penetrated about 6 ft. into the shale. A layer of brush was filled between the two upper rows of piles, and this was covered wit' earth to a level about 2 ft. below that of the road. The road was then bac' filled to the original line and covered with broken stone. No brush filling other work was done at the lower row of piles. Two trenches about 3 ft. w. were then cut in the slope, being excavated into the shale and filled wi about 4 ft. of loose rock. These works were very expensive, but accomplishe their purpose in stopping the slides. The track ditch at the foot of the slope was made of large capacity, and along it a rip-rap wall 2 ft. high was built just outside the ends of the ties to prevent washing of the roadbed by the water in the ditch. Three cross drains of 18-in. cast-iron pipe extended under the roadbed from this ditch, discharging on the downhill side. There was also a line of 8-in. drain tile laid between the tracks.

A constant trouble in cuts of wet or loose material is the gullying or washing of the slopes by rain or drainage water. This may be checked, especially in sidehill cuts, by cutting a surface ditch at some little distance from the top, so as to intercept the surface drainage. The ditch should be at least 3 ft. from the cut, with the earth thrown out on the side next the cut. It may be about 18 to 24 ins. deep, 12 ins. wide at the bottom, the size varying with the amount of water to be dealt with. The ends should be curved out, or led to a culvert or to the ditch at the toe of the adjacent bank, so that the water will not wash the face of the bank. If the earth is very soft or porous, the ditch may be lined with plank or concrete. Another method is to have drains cut diagonally along the slope and filled with bundles of brush or saplings, broken stone, or semicircular tile. To intercept water draining through the soil, trenches about 2 ft. wide and 2 ft. to 3 ft. deep are cut straight up the slope and filled with broken stone. The distance between these trenches depends upon the amount of water and the character of the material. They may be connected by diagonal or lateral drains. Where springs break through the slope, drain pipes may be inserted, and a gutter or an apron of stone riprapping laid from the outlet down to the track ditch. To prevent the breaking down of the corners of cuts and banks, these may be rounded. Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., has advocated this course, together with the paving of ditches and the sodding

of slopes. The curves would be of about 6 ft. radius for edge of bank, 10 ft. for toe of bank, 15 ft. for top of cut, and 2 ft. for roadbed ditches. Proper drainage will generally put sliding under control, and sodded slopes will check sliding and prevent surface washing. In Europe, great care is taken with the dressing of slopes of cuts and banks to a proper face; they are then covered with good soil, and finished by sodding them or sowing grass seed.

Banks may be drained by ditches not less than 3 ft. from the toe of the slope, and material should never be taken from the intermediate berm for filling the bank or raising sags. The bottom of the ditch should slope slightly away from the bank. Borrow pits near banks should be drained. If there are springs underlying the bank, tile drains may be laid from the springs to the side ditches, or the earth may be dug out, broken stone and rock filled in, and rock-filled trenches made from the hole to the ditches. Special care should be taken with the drainage on sidehill work to keep the bank itself and the ground upon which it rests well drained. In some cases benching and extra side filling or dwarf retaining walls are required to keep such a track in line. Trackmen should never be allowed to use the material from the top of the bank for ballast. The laying and cultivation of heavy soil will do much to consolidate and hold the bank. In banks of soft clay, wet spots and pockets may develop. The usual remedy is to dig out material near the top and fill in with stone, slag or cinders. If water still drains or seeps in, the conditions will not be permanently improved until the wet spots are drained and any water intercepted that may be working along the bank, as upon the old surface of a bank that has been raised. Piling may sometimes be necessary at the toe or in the slopes of banks of wet clay, to hold them from settling; but this will not be sufficient in very wet or unstable material, such as gumbo. With such material, improvement may be effected by spreading out to a slope of 1 on 3, building up with good material, putting in drains, and laying a thick bed of good ballast. (Western Society of Engineers, June, 1906.) Banks subject to the wash of waves, streams or floods should be protected by a rip-rap of rough quarry blocks or by trees or mattress work, as noted in regard to floods.

Swampy ground requires special treatment of the roadbed, and the Canadian Pacific Ry. has built some sawdust banks across swamps where gravel would break through the surface crust. The slopes are covered with earth to protect the material from fire. The Minneapolis, St. Paul & Sault Ste. Marie Ry. crosses a number of swamps in Wisconsin, many of which show soundings of 15 to 30 ft. Upon these is made a roadbed about 2½ ft. high from ditches cut at a distance of 15 to 30 ft. from the foot of the slopes. The material is mostly peat, which, when dried out, makes a very light bank. The track was laid with three lines of small poles (3 to 4 ins. diameter) under each end of the ties, and only enough ballast was used to bring the track to a good surface. The track would crawl under the influence of the heavy consolidation engines, and in some places ties 10 and 12 ft. long were used; angle bars were bolted to the middle of the rail and spiked to two ties. A 12-in. foundation of 6-in. logs is sometimes built across swamps, being covered with bushes and a little ballast.

Cuts and embankments in sandy districts are often troublesome from the effect of the wind in blowing the material away and drifting it over the tracks. This not only causes constant work in clearing, but may stall the trains, and will result in excessive wear of journals and the machinery of the locomotives.

The trouble may be reduced by sprinkling oil, by spreading cinders or gravel, and by introducing vegetation. Sand and soil binding grasses are of two kinds: (1) The larger sorts which are exposed to the severe action of winds and waves and have deeply buried roots; these send up large leaf and flower-bearing branches and grow in scattered bunches. (2) The others have prostrate stems that creep over the surface of the sand and send out long fibrous roots at frequent intervals, thus forming close mats over the ground. Along the coasts there are the sea-lyme grass along the North Atlantic, marram grass or sand weed from Maine to Maryland, and then bitter-panic grass to and along the gulf coast. They grow from 2 ft. to 5 ft. in height. There are also the St. Augustine and creeping-panic grasses in the South, switch grass, beach grass (Florida to California). The marram grass has been used for binding the sand dunes near San Francisco and by the U. S. Engineers at Coos Bay, Ore. Of inland grasses there are the long-leaf sand grass, brome grass, and redfield grass. The former is found from Lake Michigan to the Rocky Mountains, and south as far as Kansas. The marram grass is also available. In the southwest are the alkali grass, fine-top salt grass and grama grass. The propagation can be effected by seed, but it is better to transplant cuttings of the creeping grasses; the cuttings are planted about 2 ft. apart in rows 6 ft. apart. Beach grass is used for the protection of roads near Provincetown, Mass. Bermuda grass and other creeping grasses have been tried for slopes of cuts and adjacent land in the sandy districts of New Mexico, Arizona and Colorado. Soil-binding grasses on loamy or clayey soil form a compact turf. Couch or witch grass may be used in the north and middle states for holding embankments; they are good hay grasses, but objectionable in fallow lands, owing to the widely spreading and very persistent jointed roots. Johnson and Bermuda grass are better in the South. The latter is especially adapted for light, sandy soil, or knot grass if the land is moist and clayey. When Johnson grass is once well established, it is almost impossible to eradicate it.

On the Cape Cod Division of the New York, New Haven & Hartford Ry., the slopes of sandy cuts and banks have been protected from rain and wind by encouraging beach grass to grow on them. As the grass would not grow so well on the slopes of cuts, old ties were sometimes laid on the latter, but this was very unsightly. The Southern Pacific Ry. was built in sand through a part of southeastern California, and sometimes suffered during high winds. This was checked by embedding dry brush in the embankment, with tops and branches outward. The railway has also sprinkled the slopes of sand cuts with oil, using a frame 30 ft. high (on a flat car) to carry the nozzle; this will spray to a distance of 50 ft. from the track. The Atchison, Topeka & Santa Fé Ry. has blanketed the slopes with cinders, gravel, clay, or the cleanings from stock cars. On the San Pedro, Los Angeles & Salt Lake Ry., some difficulty from shifting sands was overcome by spraying crude petroleum (with a heavy asphalt base) over a width of 30 or 40 ft. from the center of the track. The volatile constituents in the oil evaporated and left a thin asphaltum crust which prevented the sand from being disturbed by wind. The sand beyond the oiled zone, when moved by the wind, was carried over the oiled crust and across and away from the track. In India, broken brick and stone are used. Where the Siberian Ry. crosses sandy plains, the roadbed is protected by rows of low scrub bushes, which serve both to prevent the sand from being blown away and to consolidate the soil by their roots.

Subdrainage and Tile Drains.

Subdrainage is frequently necessary where the roadbed is in damp or wet ground, and where trouble is caused by heaving. Tiles and broken stone are used for this purpose, the tile being generally the better. Wooden box drains, pole drains, or trenches filled with saplings may be used in wet cuts. Good track cannot be maintained in wet and soft places without subdrainage, and there are many spots in cuts and under banks (especially in sidehill work) where water seeps through and where nothing but subdrainage will afford substantial relief. The tile drains are usually laid under the ditches on one or both sides of the track. On double track, it may be under the middle of the roadbed, with laterals about 500 ft. apart. A depth of 2½ to 3 ft. below the bottom of ditch is generally sufficient, but the drain should be below the frost line to protect the tile from heaving or breakage. The ends of the drains discharge into ditches leading to culverts or waterways. In wet cuts the tile may be laid in diagonal lines at a depth of about 3 ft., and 6 ft. to 20 ft. apart, or to form lateral drains leading to the side drains, while the slopes may be drained by tile laid in trenches and connected with the side drains The common red clay drain tile without collars is generally used, but vitrified tile with open bell-and-spigot joints is used in some cases. The red or porous pipe is supposed to admit water through the sides as well as at the joints, but, on the other hand, it is believed that the clay soon becomes impervious, so that the smoother vitrified non-porous pipe open only at the joints will give equal capacity and better flow. Cement pipe is also being used. The drain should be not less than 5 ins. diameter, and of ample size to carry off all the water freely, as there is little difference in the cost of laying. Porous drain tile is usually in 12-in. lengths, while the vitrified pipe is in 18-in. lengths. Great care should be taken to lay the drain properly, getting tight joints and uniform grade with all the fall the outlet will allow. The grade should not be less than 3 ins. to 100 ft. Tile should be covered with marsh grass, if possible, although hay or straw are better than nothing. The joints should be covered with strips of sod or turf. The trench is then filled with cinders, gravel or other porous material. Stiff clay may be used, but sand or loam laid directly upon the drain will work its way into the pipe. The trench, however, may be filled with such material. In laying in quicksand or mud it may be necessary to use a plank bottom or trough covering as fast as laid, to prevent displacement. Where subdrainage is required in wet cuts on the New York Central Ry., the trenches are 3½ ft. deep, with 6-in. or 8-in. drain tile laid in a V-shaped trough of hemlock planks 1×6 ins., butt-jointed. The tiles are laid with open joints, covered with strips of sod; over this is a layer of gravel, and the trench is filled with broken stone. At the top, this is spread over the surface of the roadbed ditch to prevent washing by the cross drains laid between the ties. Extensive work may be done by an extra gang equipped with the special tools used for ditching and tile laying.

When the drain is laid on only one side of the track, it should be laid on the upper or higher side to intercept water that might flow under the roadbed. Where a spring underlies the roadbed in a cut, tile cross drains may be laid at intervals, sloping slightly towards the sides and connected at each end with the tile drains under the ditches. The outlets of all drains should be looked after and kept free, especially in winter, as springs may keep water running

in cold weather. Loose stone or a cap of wire netting should be laid at the ends to keep out small animals. Both ends of the drain should be kept open and free to allow circulation of air through the drain. The cost of laying tile will vary from 25 cts. to 60 cts. per rod, according to material; it may be even more in quicksand cuts. In general the drains, if of any extent, are laid by men experienced in this particular work, and not by the ordinary section gangs, as the former can usually do the work quicker and cheaper. In laying, the tiles or pipes may be kept in line by stringing them upon a pole about the diameter of the pipe. This is left in place until a length of backfilling is done, when it is pulled ahead for another set of pipe, its heel remaining in the pipe already laid as a guide.

Roadbed Ditches and Ditching.

Drainage of the roadbed is an important factor in the maintenance of good track. Side ditches are provided for the immediate drainage of the roadbed and for carrying away all water that enters the cuts, as described under "Roadbed Cross-Sections." These ditches should be of form and capacity suited to the conditions in each case, and in soft material should be put a good distance from the tracks. In districts with much rainfall, one of the important items of track work is that of keeping the ditches clear and properly graded. Earth from the slopes and ballast from the roadbed fall into the ditches and gradually form obstructions which choke the waterway, while in soft material the ditches will gradually close up. In the spring, as soon as the frost is out of the ground, every section foreman must have his ditches properly cleaned. In the autumn he must again overhaul them, clearing out leaves and rubbish, and putting them in condition for winter. In doing this work, attention should be paid to getting uniform grades, direct line, smooth sides, an even bottom, and proper dimensions for an ample waterway. Stumps, boulders or rock edges should be removed, as bends around obstructions check the flow and are liable to catch floating objects and cause choking of the ditch. In some cases a tile drain is laid in the ditch and covered with broken stone.

The growth of grass, weeds and bushes on the slopes may be encouraged, to prevent material from falling into the ditch and also to prevent the water in the ditch from saturating and eroding the sides. Where erosion occurs, the ditch may be faced with rip-rap stone, or old ties. On curves it may sometimes be necessary to carry the water along the inside of the curve to prevent washing of the roadbed. For this purpose, the outside ditch is dammed at intervals and a drain laid across the roadbed to carry the water to the inside ditch. Attention must be paid to getting a good discharge from the ditch at the end of the cut, so that the water will not wash the adjacent bank, but will be led safely to a stream or culvert. Where no natural waterways are available for this, special methods must be taken to provide for the water. Except by special authority, the water from the ditches must not be diverted through private lands, nor must water from natural channels be diverted into the railway ditch to protect private lands from overflow. When ditching in yards, the foreman should arrange with the yardmaster and do the work at a time when the sidetrack next the ditch can be kept clear of cars. Ditches may be carried under the approaches of road crossings by square stone drains or iron pipe.

Ditching is usually done by hand and either by the section gang, or an extra

gang with a work train. The ditch should be set out with a ditching line, and commenced at the lower end, so that the work will be drained as it progresses. Grade may be given by sighting with a spirit level over stakes 100 ft. apart, and measuring the required depth at each stake. The material may be disposed of directly by casting (or shoveling); or it may be loaded upon wheelbarrows, a push car, or a work train for removal. On the Southern Ry. a portable platform is used where material can be thrown out of the cut by two castings. This consists of two posts 12 ft. long, and two horizontal pieces 10 ft. long; the latter extend into the bank and carry the platform of five 5-ft. planks 1×12 ins. The four timbers are 2×6 ins., and have holes at intervals to allow of adjusting the height of platform. In a deep cut a second platform may be placed above the first. One man on the platform can handle about as much material as two men in the ditch. This device saves much time and is carried by work trains. The material handled by casting should not be left upon the slope of the cut, as it will soon wash or fall back into the ditch.

With fairly easy digging, the cost by casting may be taken at 10 cts. per cu. yd. for one cast, or 16 cts. where a platform is used for raising material 6 ft. at the first cast and 4 ft. at the second. The second cast includes throwing the material to a proper distance from the edge of the cut. Where wheelbarrows are used to remove the material and used in widening banks, the cost will be about 16 cts. per cu. yd., with 125 ft. haul. Where material is to be carried across the tracks, and the traffic makes it undesirable to lay planks for wheelbarrows, the men can carry it in boxes having two straight handles projecting from each end. Where the material is loaded on push cars for removal, the car must be protected by sending out flagmen while the car is run to the end of the cut or the desired point on the bank. It is usually unloaded by shoveling, but the cost may be reduced by using a three-sided box on the car, so that the material can be dumped. This is one of the best methods of working, if it can be done without interfering with trains. In many cases, however, wheelbarrows are more convenient. The wheeling planks should never be laid close to the inside of the rail, as they may be warped or tilted so as to catch the flanges of car wheels. Wheelbarrows having grooved wheels to run on the rail head are sometimes used, and are claimed to be specially useful where the traffic is heavy. In wheelbarrow work, the foreman should put one of his best men in front and a second best man at the rear of the wheeling gang, so as to get out to the dump and back again as quickly as possible If the work is extensive, a work train and extra gang may be assigned to it, the earth being loaded on flat cars and hauled to any convenient place for deposit. Whether it is best to employ trains, push cars, wheelbarrows or casting will depend upon local conditions, including the number of trains during working hours and the extent of work to be done.

Ditching Machines.

On many railways a considerable amount of money and labor must be expended for drainage; and the forming, clearing and enlarging of the side ditches are expensive and troublesome items of work in maintenance of way As already noted, the work is usually done by hand, either by the regular section gangs or by an extra gang with a work train. This is tedious and expensive, especially in wet and sticky material, and where the work is heavy or

continuous. These conditions have led to the introduction of ditching machines in order to expedite the work and reduce the cost of labor. According to a report of the Roadmasters' Association, 1904 ("Engineering News," October 27, 1904), the cheapest method of ditching, where the material is to be used in widening embankments, is by a ditching machine that can load and dump 5 cu. yds. in 2½ minutes (exclusive of running time), and can be operated by three men besides the train crew. Also, if the conditions allow such a machine to be used up to a haul of 1,200 or 1,300 ft. in fair digging, or up to 1,900 ft. in bad, wet digging. With a longer haul, a machine arranged for loading a full train of material, and used in conjunction with a plow and cable or other method for quick unloading, can be worked most economically.

Ditching machines may be divided into two general classes: (1) Those which load a scoop on one or both sides and then run to the end of the cut to dump the material; (2) Those which load a full train of material, to be unloaded by plow or by hand. The first can be used to advantage only where the haul is comparatively short, while the second is economical for a long haul.

A convenient machine of the first class consists of a flat car fitted with a heavy frame supporting two derricks at the side (or two derricks on each side for single-track work). The derrick chains support the front and back bails of a ditching scoop of 1 to 3½ cu. yds. capacity, and a chain from a horizontal bail in front of the scoop is fastened to a beam projecting from the front of the car. This chain does the pulling, the others regulate the depth of cut, and the derrick regulates the distance from roadbed to ditch. There is a man at each derrick, and the crew consists of about 8 men, or less if the machinery is operated by steam or compressed air. The machine will work in dry cuts when they have been plowed, but it works best in wet weather, when the material is soft. The car should be strong and well braced, and have the spring hangers duplicated or reinforced, as it is subjected to severe strains. To prevent jerking, there should be no slack between the engine and the car. Cars of this kind are used on a number of railways, and can be fitted with a ditching plow, a ditching scraper, or a mold board for dressing ballast slopes (as noted under "Ballasting"). The machinery may be enclosed, and the cabin or body provided with a blacksmith's forge, tools, etc., for making repairs.

Some machines of the second class resemble a light steam shovel mounted on a turntable on a frame which travels along the floors of the cars. They weigh about 20 tons and handle ½-yd. or ¾-yd. buckets, the excavating capacity being from 200 to 600 cu. yds. in ten hours. The reach is about 20 ft. from the center of track and 3 or 4 ft. below the rails. The machine may have propelling gear or may haul itself along the train by a cable attached to one of the cars. To give a steady foundation, especially when the machine is at the end of a car, a stout post may be set under the sill of the car, resting upon a tie. The Mahoney machine is for use on a work train fitted with a rapid-unloader plow and cable. A frame traveling along the cars has a 25-ft. boom pivoted near the bottom of the frame, while the rear end of the boom rides on a curved guide extending from the center of the car to the ditch. The boom carries a 1-yd. or 1½-yd. drop-bottom scoop, and is operated by a cable from the engine. In starting, the machine is at the rear end of the train, and the bucket is lowered to position. The train then pulls ahead until the bucket is filled, when the boom is swung up and dumps its load on the car. The plow cable is used to haul the machine along the train as the cars are loaded. There is an engine-

man for the unloader engine, a man to trip the bucket door and to adjust the scoop before the train moves, and a third man to couple up the cable for moving ahead. With this crew and a train crew it is said that the machine can do the work of 100 laborers.

Ditches are sometimes cleaned out by means of a wing snow plow or spreader car (see "Ballasting"), the necessary cutters being attached to the wing or spreader. The same machine may be used for trimming ballast slopes, and similar work. On the Intercolonial Ry., the wings of a snow plow have been fitted with cutters of ⅞-in. steel, 13 ins. deep, 9 ft. long. The first cut is made with the wings half open, cutting the ballast slope. The second cut is made with the wings spread to their full extent, forming the berm at the level of the subgrade and plowing the material out of the cuts and down the bank. The machine is hauled by a locomotive, and can clean 20 to 25 miles of track in a day, making a cut on each side 3 ft. to 9½ ft. from the rail and to a depth of 2 ft. below the top of the rail. The crew consists of two men to extend or close the wings, and two men to raise and lower the cutters at crossings and switches. Such a machine is specially valuable on single-track roads with limited section forces.

CHAPTER 21.—TRACK WORK FOR MAINTENANCE.

The maintenance of way includes the various kinds of work required to keep the track in safe and proper condition for traffic. The details vary with the climatic conditions; and also vary with the character of the track and the amount of traffic, being specially hard under conditions of light track carrying heavy traffic. If the road has been carefully located and built, with easy curves, well-arranged grades, and substantial track, then the maintenance-of-way department can maintain a good track at small expense. If, on the other hand, the road has been laid out carelessly, and built with a main view to cheapness, and if it has narrow cuts and banks, a superfluity of curves, and long steep grades used unnecessarily, then there will be continual trouble to keep the track in reasonably fair condition. Many railways now recognize the principles of economics, and in building, improving and maintaining their lines they are applying these principles with some regard to traffic conditions. With such a system, material economy may be expected in the labor and expense of maintenance. It is not sufficiently recognized by executive officers that where light track carries heavy traffic, and is in the hands of cheap, incompetent labor, the increased cost of maintenance may exceed the interest on the investment for new material and reasonable wages. Heavier and stiffer rails, which distribute the weight of trains over a greater length of track and give but slight deflection, materially reduce the work of maintenance, as noted under "Rails" and "Track Inspection." The cost of the work varies from $[illegible]00 to $1,000 per mile, and the following table shows the distribution of labor cost for maintenance work on the Delaware Division of the Erie Ry. in 1894:

	Per mile.	Per c't.		Per mile.	Per c't.
Surfacing	$151.46	37.8	Helping other departments	$45.68	11.4
Renewing ties	45.68	11.4	Construction and new work	4.81	1.2
Other track repairs	90.16	22.5			
Snow and ice	14.43	3.6	Total	$400.70	100.0
Wrecks, slides, etc.	48.48	12.1			

From 60 to 75% of the damage and wear to track is caused by the engines or engine mileage, and the balance by the trains, with their far greater number of wheels. This is due to the greater wheel loads of the locomotives, the closer concentration of these loads, and the destructive effects resulting from bad counterbalancing, slipping of driving wheels, use of sand, etc., to say nothing of the wear of frogs and switches by badly worn driving-wheel tires. The car is merely a passive rolling weight, and while flat spots in car wheels or the general use of very heavy car loads may aggravate the destructive effect of the wheels, it is not probable that the proportion of damage due to the train would approximate that due to the engine wheels. Freight trains are usually more severe upon the track than are passenger trains, as the engines of the former are more liable to be pulling hard, while the cars ride harder owing to the spring rigging being more rigid than on passenger cars. Day cars weigh about 30 to 60 tons, and sleeping cars 50 to 70 tons. The lighter car on four-wheel trucks gives 7,500 lbs. per wheel, while the heavier car on six-wheel trucks gives 11,700 lbs. per wheel. These weights are distributed by two trucks with a wheelbase of 6 to 12 ft. each, and giving a total wheelbase of 40 to 60 ft. Freight cars have a wheelbase of 20 to 35 ft. (with 5 ft. to 6 ft. for each truck); they weigh 15 to 25 tons empty, or 30 to 80 tons with full load. These give wheel loads of 3,750 to 20,000 lbs. per wheel. Locomotives have driving-wheel loads of 8 to 12 and even 15 tons, and impose loads of 65 to 100 tons on a driving wheelbase of 14 to 17 ft. The total load on the length of track covered by this wheelbase must be considered, as well as the concentrated load per axle or per wheel. The loads given are merely static loads, and their effect as dynamic loads when the trains are in motion must also be taken into consideration. At high speeds the counterbalances in the driving wheels may have a very destructive effect on the track. Rails, frogs and switches are also subject to injury from engines with badly worn tires. All such cases of damage should be promptly reported, and the transportation department should adopt strict rules as to the speed at which "dead" engines may be hauled. There is a certain relation between the cost of maintenance of track and rolling stock, defects in either one having a tendency to cause or increase defects in the other.

Most railways have rules as to methods of maintenance work, but the road-masters and foremen cannot always follow them, but must be governed by conditions. One principal reason for this is the lack of system in regard to employing track forces. Not unfrequently orders are sent out to reduce forces at the time when work is in full swing. This must have a detrimental effect upon the work and upon the men, as the foremen and laborers become discouraged at having to do the hardest part of the work with a small gang. Under such conditions of uncertain employment, also, it is difficult to get good men to take service with the track gangs, and much of the work must be done by extra gangs of inexperienced foreign laborers. Under such conditions, good and economical work in maintenance-of-way cannot be obtained. The principal part of the regular maintenance work is that of keeping the track in proper line and surface, both of these features being subject to constant disturbance under heavy engines and traffic, while climatic conditions also have a disturbing influence. This work includes tamping, bolting, spiking, etc. The switches and turnouts also require considerable attention, and ditching is an important feature which has already been discussed. In addition to this there is the

mowing and clearing of right-of-way, dressing of ballast, and general policing and inspection. The routine work is varied by such extra or special work as ballasting, renewing ties and rails, putting in turnouts and sidings, tile drainage, etc. In case of any important work being undertaken that may affect traffic, the operating department should be notified in advance.

The regular work should be done systematically, and not at scattered points along the sections. Standards should be adopted and followed as closely as practicable. The amount of time and labor which may properly be expended on the appearance of the track depends largely upon the financial conditions. Hand-dressed ballast, turfed slopes, etc., can be expected only on comparatively wealthy roads. Neatness should be seen on every road, as it involves no expense, but is rather conducive to economy. Mere ornamental work, such as nicely dressed but poorly tamped ballast, is evidence of carelessness or incompetence. It may seem unnecessary to remark upon the necessity of good work, but even on leading roads, track carrying fast and heavy traffic may be seen with loose ties, low joints, loose spikes, battered frogs and switches, rail joints with bolts missing, ties misplaced, ballast untidy and unevenly tamped, etc., and work done to look well. It is not always possible for the roadmaster or engineer to get what he considers desirable or even necessary. He may consider tie-plates to be more effective than rail braces in maintaining gage on curves; but if his road will not supply the plates, he must use the braces to the best advantage. He may also have bad sags in the grade line, causing trouble with freight-train couplers; but if he is unable to get the material necessary for filling, he must do his best to ease off the track at the ends of the sag to give a more even approach.

In the general work on the section, the roadbed slopes and ditches must be maintained according to the standard plans, and if the original construction does not conform to these standards, they should be aimed at in the work of maintenance. In some cases the standard dimensions (as for ditches, etc.) may not be sufficient under special or local conditions, and in such cases they should be exceeded so as to give the required capacity. Material taken out in widening cuts or in ditching should be hauled away and used for widening banks, being shoveled clear of the ties and below the level of the bottom of the ballast, so as not to interfere with the drainage. The ballast must be kept free from weeds and in proper slope, being promptly restored to shape when broken down by stock or trespassers. Center and grade stakes should be tested and reset every three or four years, and on sharp curves and transition curves the center stakes (as well as the curve in the rails) should be tested once a year. The track must be maintained in line, gage and surface, for any deficiency in one affects the others. Besides the maintenance in detail, the condition of the division as a whole must be seen to. The profile and alinement should occasionally be tested, especially where maximum grades limit the hauling capacity, as any increase in the grades or curves, or improper compensation of grade, may seriously affect the train service or the economy of operation.

One of the greatest causes of bad track, hard riding track, and damage to rails, is the low rail joint. When a joint has once become low it rapidly gets worse unless promptly attended to. If the ballast under such a joint is dirty or bad, it should be cleared away, and good ballast put in and well tamped. The Southern Pacific Ry. requires that after new rails are laid, and after extensive redriving of spikes or new spiking, the roadmaster must examine the

rail for nicks, hammer marks or defects. If these are serious, angle bars must be bolted to the rail. When a broken rail is found it should be at once spiked, and, if possible, a pair of splice bars placed at the break and bolted or spiked. Trains should be flagged until the broken rail has been securely spiked and spliced or a new rail put in. An investigation should be made and a report prepared in each case of rail fracture. Switches should be frequently examined, to see that the switch rails have the proper throw; the switch rods adjusted to give the proper position of the rails, connecting pins in place and secured, and slide plates oiled and free from dirt, stones or other obstructions. Spring-rail frogs must also be looked after and kept free from obstructions. Where a track circuit is used in connection with the block system, etc., care must be taken that the bond wires at joints are not cut or broken. If any are accidentally broken, they must be at once repaired by the foreman, and a man sent to look to the signals affected.

In many items of maintenance work, the amount of the work has little, if any, relation to traffic tonnage or track mileage. These include mowing and clearing right-of-way; maintaining fences, signs, cattleguards and road crossings, and the cleaning of ditches. The cost of such items may be regarded as fixed charges. The wear of rails, fastenings and switches is directly influenced by traffic, but the principal feature of maintenance work thus influenced is the constant work of keeping the track in line and surface, and which is comprised under the general term of "surfacing." It has been suggested that maintenance-of-way might be done by contract, but this is a class of work that it is much safer and better to have done by the railway company's men and under its own direct control. In this connection it may be noted that where contract work involves any connections with or interference with main track, the railway company usually reserves control over the watchmen and the work at such points. (See "Permanent Improvements.") Payment of section men on the piece-work system has also been suggested, but in view of the varied and shifting character of the work done by each man, the application of this does not appear to be practicable or to offer any advantages. Thus in tie renewals, each man will do more or less handling and carrying, or general helping, and it would not be economical (even if practicable) to assign certain men of an ordinary section gang to attend exclusively to certain items of work. In renewing ties, the work includes such items as removing spikes, loosening ballast, jacking up rails, pulling out old ties, carrying and placing new ties, spiking, tamping, dressing, and the removal or stacking of the old ties. The time and energy expended in devising a piece-work system to meet these conditions could be spent to better advantage in developing and introducing a record system which will insure an accurate record of the time worked by each man and the actual work done by the gang each day. Several attempts have been made to average the daily capacity of a section man in different classes of work, and the number of days' work of one man required to perform certain items of work. These are of use in a way, but cannot be relied on for actual results in practice, owing to the extreme and unrelated variations of the factors of track, traffic and labor. Some figures prepared by Mr. H. M. Church, of the Chicago Great Western Ry. ("Railway Review," March 18, 1905), are condensed in Table No. 26.

Very little has been done in the application of machinery to track work. Pneumatic surfacing machines (for blowing fine ballast under the ties when

raised), pneumatic and electric tamping machines, pneumatic rail drills, and hand or electric rotary wrenches for putting in screw spikes, have been tried. A section car with a 12-HP. gasoline engine driving a shaft with couplings for flexible shafts, has been introduced on the Atchison, Topeka & Santa Fé Ry. This operates rail drills, spike-hole augers, and wrenches for screw spikes It has been suggested that the work and the handling are too rough for machines but this is not the case. It would, however, be better to have a small force of skilled men permanently employed (as in Europe) and operating machines, than the large forces of unskilled and ignorant labor now often employed, and constantly changing. Apart from mechanically operated tools, the labor-saving equipment used in track work includes rail-handling machines, weed burners, self-propelling section cars, and ditching machines.

TABLE NO. 26.—AVERAGES OF LABOR FOR MAINTENANCE-OF-WAY.

(A. Average Work of One Man for a Ten-Hour Day.)

Renewing Ties.—Main track: 8 ties in stone ballast; 10 in gravel; 15 in earth ballast. Sidetrack: 15 ties in gravel, cinder or earth ballast. Switch ties, 8.

Surfacing (including raising, tamping, lining and dressing).—In stone ballast (with tamping pick), 35 ft.; 50 ft. in gravel (with tamping bar); 100 ft. in gravel (with shovel); 300 ft. in earth.

Scurfing Roadbed (2 acres per mile; twice a year).—In stone and earth, 1/8 mile; 1/6 mile in gravel.

Clearing Right-of-Way (100 ft. wide, less roadbed; 10 acres per mile).—Mowing, 1/10 mile. Burning, 1 mile.

Cleaning Ditches.—500 ft.

(B. Relative Labor Cost of Surfacing One Mile of Track.)

Rail.	Main Track: Stiffness of rail, per cent.	Main Track: Stone ballast, days.	Main Track: Gravel and cinder ballast, days.	Branches: Stiffness of rail, per cent.	Branches: Gravel and cinder ballast, days.
60-lb.	64	122	105	100	bar, 105; shovel, 53
75-lb.	100	97	68	150	bar, 71; shovel, 35
85-lb.	128	75	53	—	—

In tunnels, the work of maintenance is done under special difficulties. Where traffic is heavy, and the conditions are unfavorable, the surfacing, renewing of rails and ties, etc., is not only difficult and dangerous, but slow and expensive. Under such conditions it may be desirable and economical to introduce a special and more permanent type of track construction, as described under "Roadbed." In short, dry, well-ventilated tunnels the difficulties will be at a minimum. They will reach their maximum in long tunnels where smoke and gas make it impossible for men to work until some time after a train has passed. Where the traffic is heavy the men cannot work to advantage, as they have to be continually getting off the track and seeing that tools, etc., are clear of the rails. In damp tunnels, the life of rails is likely to be reduced by corrosion and other influences, and it may pay to paint them before they are laid. Ties and rails are handled with difficulty, tools and materials are easily lost and mislaid, the quality of the tamping is not easily seen, and it is difficult for the foreman to sight the rails and level boards. The work should be lighted for a length of 150 to 200 ft. Portable electric lights, large oil lamps or torches, and the Wells or similar flaming lights may be used. There are special difficulties also in track work on elevated rapid-transit railways, where much of the work must be done at night, when traffic is at a minimum The maintenance of track on bridges and trestles is of a special character. When the track is found out of line or surface at such structures, the roadmaster

should make an investigation and notify the officers of the bridge department. Temporary repairs should then be made, if necessary, and "slow" signals put up until the track has been inspected and rectified.

Protection of Track Work.

All work must be done with due regard to the safety of trains and workmen. Hand cars must be run with caution, and slowly in foggy weather and through towns or near grade crossings. They should not be used in foggy weather unless the place where the men are to work is more than a mile distant. They must not be run within 20 minutes of the time of a regular train, nor in the wrong direction on double track. It is best to start directly after a train (care being exercised as to trains following closely), and on single track to then run the car at full speed to such a point as a train in the opposite direction may be expected. If there are curves and cuts on the line, obstructing the view of the track, a man may be sent ahead as far as he can see the car and also see farther along the line. If he signals that there is no train approaching, the car can be run up to him at full speed, but if he signals that a train is approaching, there is ample time to take the car carefully off the track. If the car is left near a road crossing while the men are at work, the wheels should be locked, but it is best not to leave it in such a place. Rails should not be carried on the hand car except in cases of emergency. Loaded push cars must be operated under the protection of flagmen, and where they run through switches these must be thrown by the foreman, who is responsible for their use. Hand cars and unloaded push cars must be lifted from one track to the other at switches.

Before disturbing the track for rail renewals, etc., in such a way as to make it unsafe for traffic, the foreman must send out a watchman with a flag and torpedoes, these signals being put in both directions on single track. Some roads require the flags to be set at a distance of 24 telegraph poles, and the torpedoes at 32 poles from the work. On the New York Central Ry., a green flag (or lamp at night) is set 3,000 ft. from the work; and a white flag (or lamp) 30 ft. beyond the work indicates to the engineman that he has cleared the limits and can increase speed. Where the track, culvert or bridge repairs will last more than four days, a warning sign is erected 3,000 ft. from the spot. This is a green board 15×36 ins., lettered in white: "Reduce speed to — miles per hour"; the required speed is lettered on a sheet-iron plate set in a pocket on the board. At a train length beyond the work is a similar sign, being a white board lettered in black "Resume full speed." A green lamp is hung on the first and a white lamp on the second sign. The Southern Pacific Ry. requires that when work is being done on track or bridges that makes it unsafe for trains to pass, or when it is necessary to stop a train, a man with a red flag (or lamp) must be stationed 90 rails or 15 telegraph poles from the point at which the train must stop Torpedoes must also be placed, and not removed unless the flagman's signal is answered by the engineman. A yellow flag (or lamp) at the same distance is a signal to trains to run slowly on account of track repairs or defective track. If a flagman cannot be spared, the flag stick may be driven firmly in the ground in a conspicuous position. The Louisville & Nashville Ry. requires a red flag and torpedo at 18 poles (2,700 ft.), and a green flag at 24 poles (3,600 ft.), the man to work near the red flag. The green flag may be omitted for only temporary obstructions. If trains must

stop, a red flag and one torpedo are placed; if they are only to slacken speed, a green flag and two torpedoes are used. A man should be put in charge of the "stop" signal, being provided with tools for doing track work in its vicinity. Sometimes this is done only when the flag cannot be seen from the place where the gang is working. The man should work at some little distance within the flag limit, so as to be ready to attract the attention of the engineman if he should fail to observe the signal. The same signals are used in case of any obstruction on the track, lamps replacing the flags at night.

Special precautions should be taken on long trestles and in tunnels, and in both cases refuges should be provided at intervals. In tunnels these are recesses about 7×4 ft., and 2 ft. to 3 ft. deep. Ordinarily they may be 200 ft. apart on each side, staggered as to position. Where the traffic is very heavy, however, they may be about 50 ft. apart, and either staggered or opposite. Care must be taken to put out "slow" signals for trains, and the foreman must allow the men ample time to get clear of the track in advance of a train. When important work is being done, some form of visual or audible signal may be installed in the tunnel, and operated by the flagman to warn the gang of the approach of a train. Where the block system is in use, a temporary signal in the tunnel may be operated from the circuit of the automatic signals, or by the signalman in the nearest tower of the manual block system.

When one gang of trackmen, bridgemen, etc., passes another, the foreman of the passing gang must ascertain what signals the working gang has put out. A repair gang must not work between another gang and the latter's flagman or signals. If it is necessary for a section gang to work in such a position, as between an extra gang and the flag of the latter, a flag should be placed in the middle of the track, 100 ft. beyond the section gang (between it and the other gang), to warn enginemen that there is a second gang at work. No work that will obstruct the track or interfere with the passage of trains must be undertaken in foggy weather, during a snow-storm, or in times of exceptionally heavy traffic (except in case of emergency). The foreman must have his gang clear of the track, and the track in safe condition 10 minutes before the time at which a regular train is due, except when the train is 30 minutes late, or if permission is given by telegraph or written order. In either case he must protect the gang by means of flagmen. He must be ready for extra trains at any time, and must look out for signals carried by the trains.

Train Signals.—Two green flags by day indicate the rear of the train, and if these are not shown it is evident that some of the cars have broken away or the train has parted. At night, the markers are two tail lamps on the rear car (showing a green light at front and side and a red light to the rear). There is also a red light on the rear platform of a passenger train and on the cupola of a freight-train caboose. When the train is standing on a passing siding, the tail lamps must show green at rear, front and sides. Two green flags by day (or lights by night) on the engine indicate that another section of the train is following on the same schedule time. The engine of the last section of any train carries no such markers. Two white flags by day (or lights by night) indicate an extra train. A white light on the platform of a passenger car, roof of freight car or rear of tender, indicates that the train or engine is backing, the engine then carrying green flags or red tail lights on the bumper beam. Two white lights are carried on the rear of a yard engine at night, except when it has a headlight at each end. In signaling by hand, the indications with

a lamp or flag are as follows: Swung horizontally across the track, "Stop." Raised and lowered vertically, "Proceed." Swung in a short circle across the track when train is standing, "Back up." Swung at arm's length across track when train is running, "Train parted." One torpedo means "Stop." Two torpedoes 100 ft. to 200 ft. apart mean "Reduce speed and look out for stop signals."

Season's Work.

General improvements, tile drainage, reballasting, etc., can best be carried on from late spring to late autumn. All such work should be planned beforehand, so that (for instance) the track may not be disturbed for reballasting just after the section gang has completed surfacing. Work trains and floating gangs for ditching, ballasting, widening cuts, etc., and special gangs on new interlocking plants, rearrangement of yards, repairing or building structures, etc., may be worked at any time from the end of one winter to the beginning of another. For the ordinary work on the sections, no set rules or program of procedure can be formulated, as the requirements vary in different sections of the country, and with varying conditions of track and traffic. In general, however, the year may be divided into four seasons, and the work done during these seasons is practically as outlined below. The foreman should plan out his work in advance, and with the assistance and approval of the roadmaster.

Spring.—As soon as the winter is over, and the frost out of the ground, the work of reducing and removing the shims should be commenced. The frost will, of course, remain longer in the roadbed in cuts than on exposed banks. Soft spots in the roadbed must be noted for improvement by filling or drainage. Ditches must be cleaned out to give free passage for melting snow and in readiness for the rainy season. All spikes must be driven tight, bolts tightened, switches examined, cattleguards and road crossings cleared and repaired, ditches cleaned, fences repaired, portable snow fences taken down and piled, rubbish and old material cleared from the right-of-way and burned, and sign posts and telegraph poles straightened. Low joints are raised, and the necessary lining is done to put the track in good condition previous to the more extensive work later in the season. Sidetracks and yards may be overhauled. When the weather is settled, and all bad or low spots are fixed, the gang is then increased to its maximum number, and the work of renewing ties is commenced, the ties having previously been distributed on the section. Most of the time should be devoted to this, all ties being thoroughly tamped as soon as they are in place. The track should be lined, and low joints raised, as this work progresses. On some roads the tie renewals are done quickly at the beginning of the season, while on others this work is spread out through the season. The former is by far the better plan. As soon as this work is completed, the work of thorough surfacing preparatory for the heavy summer traffic is then commenced. The lining is done first, on account of the bad line resulting from the tie renewals, but the surfacing should follow very closely. The gaging is done at the same time. Ballasting is done sometimes before and sometimes after the new ties have been put in. The latter method involves less disturbance and leaves the track in good condition after the surfacing.

Summer.—Surfacing and rail renewals may be done at any convenient time between spring and winter. The new rails are sometimes laid before the ties

are renewed, so that the new ties will be properly spaced; but usually it is better to put the ties in first and have them thoroughly tamped, especially if there are many renewals. A general inspection of spikes, bolts, nuts and nut locks is then made. All worn, bent, broken or improperly driven spikes are removed, the holes plugged, and new spikes are driven. Broken or loose bolts are replaced. Switches and switch connections, frogs, guard rails, etc., need careful inspection. As fast as the regular surfacing is completed, the ballast should be dressed to the standard cross-section, and the toe of the slope lined to a "grass line" about 7 ft. or 9 ft. from the rail. The ballast may be scraped or scurfed three or four times to kill the weeds and keep the track clear. The drainage, correction of slopes, and general work not interfering with the track itself can best be done during the summer. Spare time can also be spent in trimming up yard tracks, and clearing yards and station grounds.

Autumn.—Weeds should be cut at least once a year, and oftener if necessary to keep the track clear. The best time for this is just before seeding. The grass on the right-of-way should be mowed, bushes cleared, and the piles of brush burned. In some cases the right-of-way is burned over instead of mowed, especially where there is liability of fires from engine sparks. Where fires cause trouble, a fire guard may be formed by plowing a narrow strip about 50 ft. from each side of the track. Burned or decayed trees likely to fall near the track should be removed. Old ties, etc., may be burned, and other old material cleared up. About a month before the commencement of the winter or rainy season the track should be given a general surfacing (including tamping up low joints and centers, lining, and gaging). This should be started at the farther end of the section and worked steadily to the other end. The track itself should be put in condition at the same time, and the spikes and joints seen to. Ditching must be then undertaken before the stormy or rainy period, the ditches being cleaned out and given the necessary width and grade. The more thoroughly this work is done, the better will be the condition of the track during the winter. Trenches should also be cut under switch rods and interlocking work to prevent water or snow collecting and freezing. Culverts and waterways must be cleared of brush and obstructions, and any signs of scour or undermining looked for, while streams should be examined above and below the culverts and any obstructions removed. After this there is plenty of work to be done in repairing fences and gates, repairing and erecting snow fences, and stacking additional portable snow fences where they will be needed. Track signs and telegraph poles have to be inspected, and cattle-guards and crossings cleaned up. Where the snowfall is heavy, the inside planks of farm crossings may be removed, so as to avoid the danger of blocked flangeways. Signs for flanger cars may also be put up at road crossings. Shims may be sorted by sizes; tools sharpened and repaired; and snow shovels, brooms and salt got ready. Yards and sidetracks may profitably be cleaned, drained, surfaced and repaired before the snow falls.

Winter.—With reduced track forces, the section gangs are kept busy inspecting the track and switches and making such small repairs as gaging, tightening bolts, etc. This work will occupy the time in fine weather or until the snow comes. After the ground is frozen, the time is principally spent in blocking up track and taking care of snow. During snow-storms, the switches, frogs, and guard-rail flangeways must be kept clear; also, all signal and interlocking connections. In heavy snow-storms, the section men must work in clearing

the track and help the snow gang or shovelers. During fine weather, rails, ties, lumber, fence material, etc., may be distributed, ready for spring work. Heaving of the track by frost has now to be expected, and proper precautions must be taken to keep the track in surface by shimming. The ditches should be examined as soon as any thaw sets in, and kept clear of ice or packed snow, so as to allow free passage for the water. Extra forces may be required for night duty, to keep switch connections and interlocking plants in working order.

General Realinement.

The true alinement of track is essential for economy of maintenance and for the easy and safe running of trains. Kinks or bends in tangents and irregularities in curves cause an unpleasant surging motion of the cars and nosing of trucks, which in aggravated cases may contribute to a derailment. When the road is in operation, the track centers soon become destroyed or displaced, and the effect of the traffic is to cause the track to shift more or less both on tangents and curves, and especially at the ends of curves if transition curves are not used. In spite of the routine work of lining on each section, there will gradually develop considerable changes from the original alinement, including swings on tangents and modifications of curves. The varying ideas and ability of individual men will thus result in giving a line which is not satisfactorily true and has an appreciable effect upon the trains.

Where a railway has been in service foı some years with only such lining as is done in detail by the section foremen, it is likely to have many irregularities in line, due to the influences above noted. It may then be desirable to give a thorough realinement of a division or a long stretch of road, and to set up permanent monuments from which measurements can be taken to check the alinement in the future. Center stakes may be set every three or four years, and those on sharp curves tested once a year. Iron plugs, 24 ins. long, may be used to mark curve centers. In some cases monuments, consisting of granite blocks or posts, are set at the P.C. and P.T. (and P.C.C.), or at intervals of about 500 ft. around the curve. In any such thorough realinement of a piece of track, the transit should be used, and the track centers marked by tacks in stakes, as on new work. Short sharp swings or bends in tangents should be corrected, but long swings are not serious. In such work as this, it is not necessary to give mathematically straight tangents or exact curves. In fact, such refinement might often involve an amount and cost of work in shifting the track that would be far beyond any practical advantages, and might in many cases result in throwing the line off the existing roadbed. This is especially the case with long easy curves, and these may have to be compounded in relining them, in order to adjust them to the existing work. The aim is to obtain practically straight tangents (free from sharp bends) and curves of such regularity that trains will ride easily upon them.

With sights of 1 to 5 miles, as on long tangents, the center line may be sighted from the transit upon a foresight target 36×18 ins., painted red and white, and placed over the track at a water tank, etc., at a sufficient height to clear trains. Center stakes and tacks may then be put at intervals of about 750 ft. (or opposite every fifth telegraph pole). The transit is then placed over the gage side of the line rail at the starting point, and a foresight taken on a rod set at the gage side of the rail and attached to a track gage, whose center line is over the center tack in one of the stakes. Intermediate sighting is

then done on a small target on a second track gage, which is moved along about 50 ft. at a time. A lining gang for this work would consist of about three men ahead of and five behind the moving target. A useful backsight target to expedite transit work in lining curves, etc., in maintenance-of-way, is shown in Fig. 204. It is driven into the stake or tie just back of the tack marking a point, and its use saves the time otherwise lost by the whole party, when a man is sent back with rod or pencil to give a backsight. Three men with a few of these targets can work as fast in rerunning curves and tangents as four men without them. They give a well-defined sight, even at long distances, and stand so low that passing trains do not knock them out. Another target is of ⅛-in. iron, of triangular form, 3 ins. wide on top, and 4½ ins. high (including a ½-in. point which is driven into the tie).

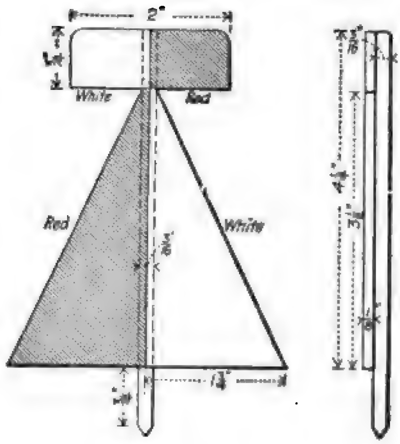


Fig. 204.—Backsight Target for Lining Track.

The following method of lining track preparatory to ballasting has been used by Mr. R. A. Rutledge on the Gulf, Colorado & Santa Fé Ry. The endeavor is to get the tangents as nearly straight as possible, but to leave easy swings where exact lining would require an excessive amount of work. The transit being set near a curve point, the line of track is obtained, and then produced to the next intersection by the following method: Two points are located 500 or 1,000 ft. apart, according to the clearness of the atmosphere and the accuracy of the object glass. The transit is next set over the second point and a backsight taken on the first, after which a third point is located the same distance ahead by reversing the transit on it with great care. The line is thus continued forward to a point near the P.C. of the next curve, and, at each point located, the distance to the right-hand rail is measured and recorded. Inspection then shows whether this is the line that best fits the track. If not, a simple calculation will show at which point to swing the line, the idea being to get a tangent that will fit the track as it is on the ground and save as much relining as possible. When the line is decided on, a calculation is made as to how much each point, already set, has to be moved to get it on this line. They are then measured in, using a tape graduated to hundredths.

The transit is set over alternate points on the selected line, and run each way by foresights, in this way getting as near a straight line as can be run, and at the same time reducing the track work to a minimum. On curves, the intersection points are obtained either by running the tangents to their intersection, or by running in long chords and calculating the curve point if the intersection is difficult of access. After establishing the curve points, the curve is run in and temporary points are established at each station. The distance from each temporary point to the outside rail is measured and recorded. after which (by calculating the external for the curve at the given degree, and for another curve either one minute more or less) it can be seen whether the curve can be improved by flattening or sharpening it. In all the work the reduction of track work is kept in mind. This method makes work for the instrumentman, but the work of a party of three engineers may save that of a track gang of 50 to 100 men. Other methods are described in "Engineering News," Dec. 26, 1901; Feb. 13, March 20 and April 10, 1902.

Lining.

This term is generally applied to the detail lining of track from time to time by the section gangs. It should be done, as a rule, after the surfacing (or raising), and should be finished up each day to leave the track in good condition. If the track is badly out of line, this work may be done before the surfacing. All kinks in rails should be corrected with the rail bender. In the work of lining, where line stakes are set, the foreman sets his gage on the rails at each center stake, and the men throw the track until the center mark on the gage is over the center mark on the stake. When this has been done at four or five stakes, the men go back and throw in the intermediate points, the foreman lining them in by his eye. Where there are no center stakes, the practice on the New York, New Haven & Hartford Ry. is that the foreman lines his track by eye, keeping a sufficient distance from the lining bars to enable him to have a good view of the rail. Occasionally when tangents or curves become badly out of line and the foreman is unable to remedy it by eye, the engineers are called upon to run a line with the transit. In the more extensive work, such as ballasting and new tracks, stakes are set and the lining is done as above described.

For short sights, as in bent rails, the foreman should bring his eye close to the rail, but for longer sights he should stand up at some distance from the work, so as to avoid putting a swing in the track. In all work of this kind, one line of rail is taken as the "line rail," and all lining is done on it, the other rail being conformed to the line thus given in the subsequent operation of gaging. After proceeding ahead for some distance, the foreman should turn and sight back as a check upon the accuracy of his work. For double track, the foreman may have a special gage for lining the inside rail of the second track from the track already lined, all measurements being made from the gage side of rail heads. For accurately lining a long stretch of track, he may sight by means of a rod or target fitted to a track gage, and having the center line directly over the inside of the rail head or at the center mark on the gage. The rod may be set vertically by means of a graduated arc on the gage. Three sighting boards may be used, resting on the rails, and having lugs or brackets to fit against the inside of the rail heads. At the center of each board is a vertical flat bar with its face on the center line. Two boards are set on the

straight track at either end of the swing. The third is set at different points between them, and the track is thrown until the middle sight is in line with the two end sights. The distant sight may have a small target to render it easily distinguishable at a distance. The Bailey sighting blocks are described under "Surfacing."

The track is usually thrown to line by from six to ten men with bars, half of the men being at each rail. The bars are stuck firmly in the ballast at an angle, and resting against the rail. As the foreman gives the word, all the men heave steadily, the movements being repeated until the track is in correct line. In lining after surfacing, care must be taken that the bars are not at too great an angle, or they will raise the track in moving it, and so spoil the surface. The work is severe, and on branch lines with small forces, or on main lines at seasons when the section gangs are reduced, it is necessarily left until such time as the force is increased or is temporarily recruited by men from other sections. In some cases it may be necessary to send a floating or extra gang to do the work. To obviate these difficulties a lining jack has been introduced, having a horizontal traverse on a base plate fitted with a rack. The jacks are used in pairs. Sufficient ballast is removed from between two ties to allow the base plates to be pushed under the rails, where they are firmly bedded. The jacks are then slid along the plates till the lifting claws are under the rails, and the track is raised until the ties are just clear of the ballast beds (but not enough to allow material to fall in beneath them). If the ballast is heavy it may be loosened around the ends of the ties. The levers are then set to work pawls engaging with the horizontal racks in the base plates, and the jacks are thus given a lateral movement. Both jacks should be set outside the rail, in which case only one does the work of throwing the track, the other being used to raise the track and serving to support it as it is moved. Two men with two jacks can throw track for lining. The jacks may also be used at grade crossings that have been thrown out of line by the creeping of the rails; this is heavy work and ordinarily requires a large gang of men with bars. The jacks may be used for ordinary track work, the base plates being placed only when track is to be lined. Track may also be lined with ordinary jacks, being raised a little higher on the inner side by a jack set at an angle, so that the track will slide off to its new position. This, however, is open to the objection of liability of dirt getting under the ties and spoiling the surface; it also requires the jack on the lower side to be placed inside the rail.

Lining Curves.

A curve should be maintained uniformly at its proper degree from end to end. Continual lining and work, or neglect, very often results in sharpening a curve at various points, so that it will ride badly. The curves should be staked out and tested periodically with the transit. but the foreman should also check them. To do this a cord is stretched with the ends touching the gage side of the head of the outer rail, and the distance from the middle of the cord to the rail head is carefully measured. This distance in inches divided by the middle ordinate for a given length of chord of a 1° curve gives the degree of the curve tested. The middle ordinates for different chords (or measured strings) for a 1° curve are given in Table No. 27. With a 62-ft. chord, each inch of middle ordinate represents 1° of curve. This table also gives the nec-

cessary ordinate for bending rails to a curve of given degree, as described under "Bending Rails." In lining curves, the foreman takes a cord 62 ft. or 100 ft. long, and at a part of the curve which seems to be true, he measures chords along the gage side of the outside rail (or outside of inner rail if the rails are worn), and measures the middle ordinates. Having thus ascertained the middle ordinate, or having obtained it from such a table as Table No. 27 or No. 28, if he knows the degree of curve, he commences at the point of curve (or point of circular curve if there is a transition curve) and measures chord lines from each middle ordinate, thus getting ordinates at intervals of 31 or 50 ft. These should be recorded and averaged (if not uniform), and the curve lined to the proper ordinate throughout. The outside rail should be taken as the line rail, beginning some distance back on the tangent, if this is not the line rail on the adjacent tangent. The line rail should be thoroughly spiked, so that it will remain in position for lining the gage rail. When the curve has been checked, the ballast should be cleared away from the ends of the ties on the side to which the track must be thrown in correcting the line. Lining with a cord is not satisfactory for transition curves, and these should be properly staked out by an engineer. Then the foreman has simply to keep to the permanent established line instead of trying to find the line for himself.

TABLE NO. 27.—MIDDLE ORDINATES FOR CHORDS OF VARIOUS LENGTHS.

Length of chord.	Middle ordinate for 1°.		Length of chord.	Middle ordinate for 1°.	
30 ft.	¼-in.	0.25	62 ft.	1 in.	1.00
44 "	½-in.	0.50	100 "	2⅝ ins.	2.625
50 "	⅝-in.	0.625	215 "	1 ft.	.....

While much mathematical and instrumental work is expended in the laying out and rectification of railway curves, yet the everyday work of maintaining the curves in proper alinement is largely a matter of rule-of-thumb practice, in spite of the important relation of curve alinement to the safe and smooth running of trains. The Smith curve gage is an instrument by which the section foreman can readily check the accuracy of his curves. It consists of a bar 5 ft. long, at each end of which is a transverse saddle to rest on the rail. Over each saddle is a flat seat on which a removable graduated scale (at right angles to the rail) is fitted when the instrument is in use. At the center of the bar is a casting having a bearing for two horizontal grooved collars, to which are attached the ends of No. 22 copper measuring wires. When not in use, the wires are coiled on a 3½-in. grooved wheel. To the end of each wire is attached a scale, graduated for curves up to 24°, and with a sliding piece which is adjusted to the exact length of chord. The instrument is made to measure 25-ft. chords.

The operation for lining curves with this instrument is shown in Fig. 205. A stake is driven in the middle of the track at the point of curve A and another at B, 25 ft. back on the tangent. The man with the instrument places it with the center point over the center of the first stake A. The rear man sets the pin at the end of his wire over the center of the rear stake B. The instrument man then shifts the bar until the rear wire is over the center mark on the scale at the rear end (when the bar will be parallel with the tangent). He then lines in the front man until the front wire crosses the mark of the given degree of curve on the scale at the front end of the bar. The front man then drives a tack at this point C, either in a stake or on a tie, and the three men move forward 25 ft. With the instrument at C, and the rear end of the wire at A

(point of curve), the instrument is swung until the center mark on the rear scale is in line with the wire, and the front man is then lined in until his wire crosses the front scale again at the mark of the given degree of curve. The operation is repeated around the curve, and gives center marks at 25-ft. intervals.

To tell whether a curve is in proper and uniform alinement, the instrument is placed on the outer rail of the curve with its center pin against the gage side of the rail head opposite the point of curve, as at W, Fig. 205, while the front and rear men also place the pins at the ends of the wires against the gage side of the rail head, as at X and Y. The instrument is set parallel with the tangent by bringing the rear wire over the center of the scale at the rear end, and the graduation at which the front wire then crosses the front scale is noted, showing the degree of curve. The instrument is then shifted to Y, with the

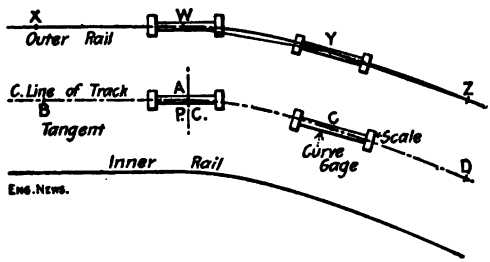


Fig. 205.—Method of Using a Curve-Lining Instrument.

ends of the wires at W and Z. The bar is swung until the rear wire crosses the center mark on the rear scale, and the graduation at which the front wire crosses the front scale is again noted. This operation is repeated around the curve. The graduation (or ordinate) shown by the front wire will be the same at each point if the curve is true. Otherwise the several readings are added together and the sum is divided by the number of readings, which gives the proper degree for the curve, and to which it must be adjusted. Where easement or transition curves are used it is a difficult matter for the trackmen to check or adjust their alinement, but this is rendered much simpler by the instrument in connection with a table of offsets.

Gaging.

The combined influence of the traffic, the wear of rail heads, and the tie cutting and spike loosening at the base of the rail, is to increase the gage of the track, and this must be corrected periodically. It is usually done immediately after lining, but it is not generally considered necessary to correct the gage where the widening is not more than ¼-in., providing that this widening is uniform for a considerable distance. Track that is in bad condition in this respect may be gaged by a few men working immediately ahead of the surfacing gang. The work consists in lining the "gage" rail by measurements from the "line" rail, the lining having already been done. A track gage is set at various points, the spikes of the gage rail are drawn, the rail thrown in against the lug on the tool, and the spikes are driven to hold it in its new position.

Surfacing.

A common and troublesome cause of bad riding track is an irregular surface, with sags, low joints, bent rails, and short depressions and humps in the road-

bed. These defects are due to heavy loads and traffic, light rails, weak fastenings, poor ballast, insufficient tamping, rails out of level transversely on tangents, and insufficient work of maintenance. The remedy for this is surfacing, or putting the rails and track in a uniform plane. The work usually includes lining and gaging also. In the general surfacing done each year, the track should be raised only just enough for proper tamping, to bring up the low parts to a uniform surface, the track being raised out of a face only every four or five years. Great care is required to prevent the section men from raising it too much, with the idea of letting traffic settle it. No raise must be made in tunnels or under structures with a headway of less than 22 ft. In stone, slag or coarse gravel, a thorough tamping can rarely be done without raising the track about 1 in. In sand, earth, cinders or poor gravel, a raise of ½-in. to 1 in. may be made by tamping without disturbing the bed of the tie. The work should be done immediately after tie renewals in the spring, and again before the winter. It should also be looked to immediately after the laying of new rails, so as to prevent the rails from being surface bent by trains running over them when they are not uniformly supported, as it is almost impossible to take out such vertical kinks. When new rails are laid, the track should be raised enough to allow all ties to be tamped to give an even bearing. The freezing of water in the ballast or roadbed in winter causes "heaving," the effect of which is to raise the track irregularly. As the frozen ballast cannot be tamped, shimming or blocking has then to be resorted to in order to bring the track to surface. The cost of surfacing averages about $150 per mile per year, increasing about 1% with each 12° of curvature.

Surfacing should be commenced at one end of the section and carried on continuously to the other end, each day's work leaving the track in finished condition. Two men should work ahead of the gang to tighten all spikes, so that the ties will come up when the rails are raised. One of the men holds up the tie with a bar while the other drives the spikes. The bolts should also be tightened. The foreman sights the line rail, and when this has been raised and tamped to surface, the track gage is laid on the rails and the other side of the track raised. The gage should be set at each joint and at the middle of each rail. The final tamping must closely follow the raising, so that the surface will be maintained under traffic. If the track is not to be raised to grade stakes, it should be carefully examined by the foreman and raised to the level of the high points. If there are only a few high points it may be better to lower these than to raise long stretches of track. The raising is done by jacks or bars. The former are preferable; they hold the track more securely at the required elevation and are less likely to throw it out of line in raising.

On the New York, New Haven & Hartford Ry., the rules require that in the general surfacing the track should never be raised above the level of the given grade, and particular attention is paid to raising at the ends of bridges. In the ordinary track surfacing, as done by the section foreman, where there is no grade given, he takes his level board and determines his high rail. After noting the low spots in this he raises the opposite side to the level, with his level board, raising the joints first and the centers and quarters as may be necessary. The raise should never extend beyond such length as the gang of men can care for between regular trains. In surfacing on curves, the inner or lower rail is taken as the grade rail and the process carried on in the same way as on tangents. After the track has been put up and thoroughly tamped,

it is put to perfect line as far as the section foreman is able to do this with his eye. The ballast is then filled and dressed to the standard cross-section.

The track level and gage should be freely used in surfacing. The track level indicates local defects in transverse surface, but it is difficult to determine the general condition of the plane of the surface. The eye cannot detect a general irregularity in this plane, and the practice is to sight one rail into a uniform plane, and then to bring the opposite rail up to the same plane by means of the track level. One way is to use a sighting board and blocks. On the New York Central Ry. the board is $8 \times 1\frac{1}{4}$ ins., 12 ft. long; it is painted white, with a 2-in. black stripe at 5 ins. from the bottom. On some roads it is black, with a white line. This is placed on the rails at a point beyond the part to be raised, where the track is already in proper surface. The foreman has a wooden block or iron target 5 ins. high, which he places on one rail at a point three or four rail lengths from the other end of the part to be raised. A similar block is placed on the rail between the board and the first block. This second block is moved from point to point, and the track is raised at each point until the top of the block is sighted by the foreman in line with the first block and the stripe on the board. Each of the two blocks (or targets) may be mounted on the middle of a track level; sighting shows the longitudinal surface, and the level bubble shows the transverse surface.

The Bailey system of sighting for surface and line uses three sights or blocks, as in Fig. 206. Each sight has an upright bar, with a foot to rest on

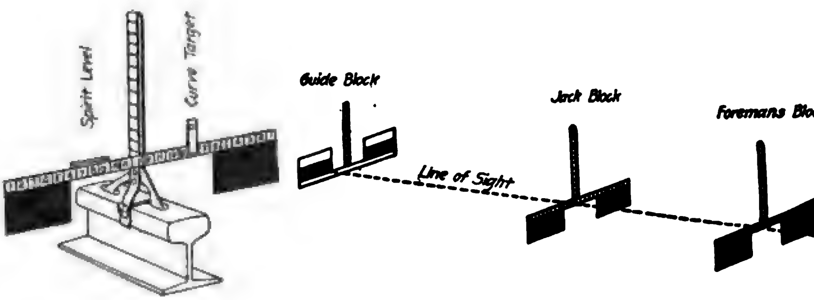


Fig. 206.—Sighting Block.

the rail and held by a side piece clamped against the rail head by a thumb screw. Across this is a horizontal arm with a target at each end. The foreman's block has the targets below the arm and painted black. The intermediate or jack block is similar, but with a graduated arm for use in lining curves. The guide block has the targets above the arm, painted white and black. In setting the blocks, a pocket spirit level is used to get the arms horizontal. For surfacing, the sight is taken over the tops of the arms on the first to the lower edge of the black stripe on the third block. The other block is set between them and the track raised to bring the arm into the line of sight. For a long sag in a stretch of track, a number of sights may be taken, the arm of the jack block being raised on the bar to bring it into line. Its position and the amount of elevation required are marked on the rail so that the track can be raised the proper amount after the sighting is done. In lining, the sight is taken along the ends of the targets. On curves, the two end blocks are set 62 ft. apart with the jack block midway between them. A small red target is then

fitted on the graduated arm of the jack block at the distance of the middle ordinate for the curve, and the sight is taken over this target.

In surfacing or raising, the track should never be brought up above the level of grade stakes or of bridges in the expectation that the traffic will settle it down to the exact grade. If the raise is at all heavy, the joints are raised first, then the centers, and then the quarters; but if it is light, the joints are raised first, and then the thirds or "long quarters," which will bring the centers up properly. The track level is then used at all joints and centers, and the opposite rail brought up as required. The raise should extend only over such a length of track as can be tamped between trains, and neither side should be fully tamped until both sides have been brought to surface. With a raise of 2 ins. or more an incline or run-off should be formed at each end to give an easy-riding approach for trains. For extensive surfacing where the track is to be raised 2½ or 3 ins. and the traffic is not heavy, the work may be done by a gang of 30 men with a foreman and assistant foreman. When the raise is over 3 ins. and the traffic is heavy, a gang of 40 or 50 men may be worked.

The lowering of humps or high places to surface is troublesome, and it may be necessary to shift the ties. In this case the ballast is shoveled out between ties 1 and 2, 3 and 4, 5 and 6, etc.; and ties 1, 3, 5, etc., are shifted into the spaces thus formed. The old beds of these ties are then leveled off as required, and the ties shifted back into position. Ties 2, 4, 6, etc., are then knocked into the open spaces, and have their beds leveled off in the same way. They are then put back. The ties should be well tamped, and the lowered piece of track tested for surface after some trains have passed over it.

With earth and other poor ballast, the section gang has to be continually surfacing, as the material will not give a uniform support under traffic, but some parts will go down while others remain firm. If the force is sufficient, the track should be surfaced and tamped in the usual way; but if the section is long and the number of men allowed is small (which is frequently the case on such roads), then there is not time enough to fully tamp all low ties and low spots to proper surface. In such cases the tamping must be done partly from above by the trains, instead of merely from below by the tamping bars. The jacks or raising bars are put under the part to be raised, as far from the finished part of track as is possible without causing the rail to sag between the jack and the finished track. The low track is then raised above the finished or desired surface by an amount varying from ½-in. for small lifts to 1½ or 2 ins. for lifts of 4 to 5 ins. Earth is then shoveled under the ties and tamped. The jacks are then removed, the track sighted for surface, and rectified if necessary. The track should be lined up before the first train passes. The train will drive the ties down to surface, and after it has passed, the surface should be finally sighted. The ballast is then shoveled under the ends of the ties, and tamped and dressed to shape for proper drainage. The best surface will be obtained if one or two men do all the filling, so as to secure uniformity. In work under such circumstances it is simply a question of how to keep the track in reasonably good running condition, without regard to appearances. Good men who are familiar with the work, however, will devise useful methods for themselves. New men, perhaps accustomed to good ballast and large gangs, may find it difficult to get satisfactory results.

The Patterson surfacing machine is intended to do away with tamping, which necessarily disturbs the old bed of the tie to some extent. A blower

using compressed air or driven by hand is mounted on a hand car or on a frame which runs on one rail and is clamped to it when at work. The machine consists of two vertical pipes, one connected with the blower by a hose, and the other having a hopper on the top for the ballast. The pipes unite in a shoe at the bottom, and to this is fitted a thin flat horizontal nozzle with variable width of opening. The material used is ¾-in. screened stone or gravel. The ballast is cleared away from the ends of the ties and the track raised to surface. The nozzle is then inserted under the end of a tie and the blower put in operation, driving the fine material into all the cavities and packing it solid. This method can be used for a raise of ¼-in. to 1½ ins. In a test on the New York, New Haven & Hartford Ry., a gang working in the usual way surfaced 5 ft. per man per hour, while with the machine the average was 8 ft. In one year, the stretch surfaced by hand required 36 hours labor for maintenance, while that surfaced by machine required only 2 hours. The machine has also been used on the Bessemer & Lake Erie Ry. for surfacing track laid with steel ties.

Raising Track.

About once in three to five years the entire track will require to be raised out of face or brought up to a new surface. This is often done by extra gangs of about 70 men. At such a time (as well as in raising out of sags of any considerable depth) grade stakes should be set to give the elevation of the top of the rail, and ballast should be distributed for raising the track. (Chapter 19.) In raising, jacks should be used under each rail. and both sides of the track brought up and tamped simultaneously. It is bad practice to raise and tamp one side first, and then bring up the other side by the track level. The raise should not exceed 6 ins. at any one lift, the 6 ins. of ballast being well tamped, and then another raise made. The jacks should be set about 2 ft. from the joints, so as to bring them up level and avoid bending the splice bars. They should never be set on the inside of the rails. The track may be raised about ½-in. or ¾-in. above grade (according to the quality of the ballast) and well tamped, on account of the tendency of new track to settle. Every foreman has his own ideas as to the proper course to pursue in tamping a raise, but a good plan is to first tamp the joint and shoulder ties, then the center tie, the two quarters, and the intermediates; finishing off again at the joints. An incline or "run-off" should be made, connecting the old with the new level, this being long enough to allow trains to ride easily over it, and to prevent the bending of the rails. If the work is extensive and the section gang is assisted by a floating or work-train gang, a part of the regular gang should follow behind the raising gang, to finish the tamping, surfacing and dressing.

In work of this kind on the New York, New Haven & Hartford Ry., when it necessitates extra gangs and where it is necessary to raise the track several inches, jacks are used under the rail and both sides of the track are brought up and tamped simultaneously. After the grade stakes have been set for the top of rail, the foreman uses two sighting boards and a sighting bob. The sighting boards are placed at some of the grade stakes and the intermediate joints are raised to the level; the bob being placed on the joint that is being raised and the foreman sighting across the two boards. The men follow behind and shovel-tamp the track as fast as both sides are raised. This work is done between trains and protected by a flagman, and a suitable run-off is made

to allow the safe passage of trains. The jacks are always used on the outside of the rail and never within three ties or about 4 ft. from joints, in order to avoid bending the angle bars. The track is never raised more than 6 ins. at a lift. In such work as this the foreman determines by experience how much above grade the track should be raised at that time, as in the first raising of the track a little is always allowed for settlement. Under no circumstances is the finished track left above grade. In extensive ballasting, when the track has been raised to the proper level, the joint ties and quarter ties are tamped at the same time, to avoid placing too much strain on the joint ties after the jacks have been taken out, which would have a tendency to bend the angle bars. In a day or two after the heavy raising has been done, a smaller gang is sent back and raises the track again to grade, thoroughly bar-tamping, relining and filling in to the standard cross-section.

Tamping.

It is not sufficiently well understood that the accuracy and permanence of surface, as well as the general efficiency and economy of maintenance-of-way, depend to a very large degree upon the proper tamping of the track. This has been shown very clearly by the investigations made by Mr Cuenot on the Paris, Lyons & Mediterranean Ry. (France). In view of the fundamental importance of this matter it is not difficult to see why deformation of track (with the constant work necessary to keep it within limits) is so serious and widespread a trouble on American railways. The tamping of ties is skilled labor, but as a rule in this country it is not done by skilled laborers permanently employed. On the contrary, it is done by inexperienced and transient forces of the cheapest grades of common labor, whose efforts are largely governed by "sheer strength and awkwardness" One of the important requirements is that the ballast must be tamped more thoroughly at each end of the tie than at the middle, the work being concentrated within a length of about 12 to 15 ins. on each side of each rail. This gives a firm and solid bearing. If thorough tamping is continued under the middle of the tie it will cause a center-bound track. Under this condition, the tie becomes more solidly supported at the center than at the ends, as this part of the roadbed receives a comparatively small proportion of the loads exerted by the traffic. This may result in a tendency of the track to rock laterally (with perhaps an unpleasant or dangerous effect upon the trains), and in a distortion of the proper line and surface. In some cases ties may be broken. The tilting or rocking of track from this cause is also suggested as a common cause of spreading rails. as it may result in greatly increasing the pressure and shocks of the wheels against the heads of the rails. One advantage of certain designs of compound ties (see "Ties") is that with a large bearing surface under each rail and a comparatively small surface for the middle or connecting portion, it is almost impossible for the track to become center bound. When track has once become center bound, the most effective remedy is to give a slight raise to the entire track and to see that the tamping done after this raising is comparatively light at the middle of the track.

The only way to maintain track in good surface is to have the ties well and thoroughly tamped. The men should work in pairs, both men of a pair being of about the same strength and activity. In some cases each pair does the entire tamping of one tie. Tamping picks are used for stone, slag, or coarse

clean gravel. Tamping bars are used for earth, cinders and ordinary gravel. In tamping with bars there should be an equal number of men on each side of the tie, standing opposite one another and striking in unison, so as to pack the material and not drive it out at the opposite side of the tie. Shovel handles make fairly good substitutes for bars in light work, or loose material. Shovel blades, however, should never be used for tamping, except at the middle of the tie in loose ballast or for the first placing of sand and gravel. The shovel has not the force or weight necessary to pack and consolidate the material sufficiently to sustain heavy loads and traffic. This may be stated very emphatically, though many trackmen working in gravel or earth ballast believe otherwise.

The joint ties should be tamped first, and then the shoulder ties. Both are tamped somewhat harder than the others, but never higher, as that will tend to cause the splice bars to crack under traffic. The object of tamping the ties next to the joint ties with extra care is to prevent the upward deflection of the joint when a wheel is over the second tie, which deflection often causes the splice bars to crack downwards from the top. As already noted, the most thorough tamping should be directly under and for a few inches on each side of the rail, and tamping from the ends will assist in getting a good firm bearing under the rail. Each tie should be fully and properly tamped before the men leave it, and it is bad practice to tamp the ends only and leave the center to be tamped later. This second tamping is quite likely to result in center-bound track. The ties at frogs, switches and crossings should be specially well tamped. Tamping machines have been tried to a small extent. The Collet machine used on the Paris. Lyons & Mediterranean Ry. (France) is mounted on a truck or push car and operates a bar with a reciprocating movement. Four machines are used, two on each side of each tie.

Renewing Ties.

The new ties are usually distributed by work trains at convenient times during the winter, so that all may be on the ground soon after the frost is thoroughly out of the roadbed. The distribution is done under instructions from the roadmaster or foreman as to the places for unloading and the number unloaded at each place. The foreman should know how many ties are to be deposited on each mile. For small lots or during a dull season, the ties may be distributed from local freight trains. In some cases the ties are not distributed along the section from the cars, but are unloaded in lots at certain points and thence distributed by push cars. The ties to be renewed should have been marked conspicuously, and only the marked ties must be removed. The work should be done before or immediately after new rails are laid, so as to give a good substantial bearing to the rails, all new ties being thoroughly tamped. All old ties left in the track should have open spike holes plugged. The work should be commenced as soon as possible after the frost has left the ground, as the ballast is then loose, while the men can work to better advantage than in the summer. Then by the time the heavy summer traffic begins, the new ties will have become well settled, and the track will require but little maintenance. If the ties are put in late, and the season is wet, they do not get properly tamped, so that they may have to be shimmed in the winter. The renewal of shims and fixing up of the roadbed in the spring then delays the new work of tie renewals. When the work is once commenced it should be

pushed steadily along and completed as soon as possible. Continual renewals of a few ties at a time all through the season prevent the track from being well settled and consolidated. This continual disturbance results in an increase in maintenance expenses and train expenses. (See Chapter on "Ties.")

In renewing ties, the spikes are first drawn from the ties to be renewed in a certain length of track, and the men then work in pairs. Each pair takes a tie, loosens the ballast, pulls out the old ties, puts in the new tie and tamps it to a firm bearing. When a number of new ties have been put in, some of the men go back to spike and gage them, leaving the track in good condition at the end of the day. The old ties should also be removed and piled, and the track dressed and trimmed each day before quitting work. The practice on the New York, New Haven & Hartford Ry. is as follows: The track foreman examines his ties and marks those that are to be taken out by chopping a small piece from the corner on one end. He also marks on the rail where he wishes the new ties to be located. In preparing to remove the old ties, the ballast is dug out to the necessary depth below the bottom of the ties, so that the old one may be pulled out without trouble. After the old tie is out, the bed is leveled off to a depth sufficient to admit of the new tie being pulled in. After the new tie is put in position it is held up to the rail and thoroughly tamped; in this position the rail is raised (not to exceed ¼-in.) to allow for settlement. As soon as the tie is tamped, the spikes are driven and the track brought to gage. The section gang is divided into pairs, as above described, and two men do the spiking and gaging. In the latter part of the day the whole gang turns back and gives the new ties a thorough tamping; they also fill the ballast between the ties and dress the track to its ordinary condition.

If a general renewal can be made, the best result will be obtained by lifting the track with jacks sufficiently to allow the old ties to be removed without destroying the bed, and then placing the new ties on the old beds and resurfacing the track. When only two or three ties are to be removed from under each rail, and the track is in general good surface, it is not desirable to disturb the roadbed or raise the track. In that case, the ballast may be dug out between these ties so that they can be removed without disturbing the remainder of the roadbed. On roads with heavy and fast traffic all track should be surfaced and tamped on the same day the ties are put in, for the reason that if the roadbed is dug deeper in some places than in others the tendency will be to settle unevenly, resulting in rough and unsafe track for fast trains. Track of this kind should be resurfaced in the course of eight or ten days, when all new ties and low places should be carefully retamped. Some roads require that the ballast beds must be loosened and new ties tamped to a firm bearing. This must not be attempted on the old bed, as the general surface of the rails would thus be raised.

Gravel ballast is cut away from the ends of the ties and loosened along their sides. The spikes are then drawn, and the rails raised by jacks just enough to allow of the old tie being knocked out and a new one slipped in on the same bed. The ballast should not be dug out under the tie, unless the new tie is of greater thickness (which it should not be), as the less the tie beds are disturbed, the better for the maintenance of the track surface. This general rule may, however, be modified where only one or two ties are to be renewed in a rail length, but in this case a loosening of the side of the tie bed will usually

enable the old tie to be taken out and the new one put in without much disturbance of the bed, and without the disturbance of the adjacent track which is incidental to raising by jacks. With stone, slag, or coarse gravel ballast, which is liable to fall onto the tie bed when the tie is removed, it is necessary to dig out the ballast at one side of the tie, and to knock the tie sideways into this trench. Some foremen prefer this plan with earth or common gravel, but the amount of digging required is liable to disturb and loosen the ballast. This plan, however, may be employed when two adjacent ties have to be renewed. If the ties are not uniform, the larger ones should be selected for the joints and for curves; and the wider end should be placed under the outer rail on curves. The ties should be properly spaced, placed square across the track (or radially on curves), and their ends should be lined at one side of the track. It is rarely economical to turn old ties, except where tie-plates are to be applied, and then it is probably better to turn the ties than to adze out new seats on the old worn faces.

If the traffic is heavy, each tie should be tamped and have the outside spikes driven at once. Otherwise, a number of ties may be renewed in succession; one man going ahead to cut the earth or gravel from the ends of the ties, two men pulling spikes, and two men raising the track with jacks. If only one jack is to be had, the rail first raised should be blocked up, and the jack then put under the other rail. When 20 or 30 ties have been thus put in, three men are sent back to do the spiking, one holding up the ties with a bar and two driving the spikes. The new ties should be tamped each day as put in, the tamping being done thoroughly with a bar or pick. The ballast is then filled in between the ties and dressed to proper shape. If the new ties are shovel-tamped, or only partially tamped with bars, and then left to be finished a few days later, the old ties will be disturbed, and a soft spot probably caused, especially if rain falls before the tamping is done. The second tamping, also, is likely to cause center-bound track. No train should be allowed to pass over untamped track, the foreman taking it for granted that it is safe.

At the end of each week the ties removed should be properly piled on the right-of-way, at a convenient distance from the track if they are to be loaded on cars, or midway between the track and the fence if they are to be burned. They should not be left in the ditches or scattered about the right-of-way. Ties may be burned in small piles of 5 to 10, or in large piles of 50, but the former is usually the better and safer plan. The piles should not be near the track, as the intense heat is injurious to the paint and varnish of cars. Large piles should be burned in damp weather to reduce the danger from fire, and in all cases the burning piles should be watched to prevent fire from spreading to fences, fields, etc.

In a few cases the practice has been adopted of renewing all ties at once. That is, each year a certain length of track on each section or division has all ties removed and new ones put in. The remainder of the track receives ordinary maintenance. The objection to this is that ties have a very varying life, so that on the portion re-tied a large number of good ties must be removed, while on the other portions a number of poor ties will be left in place. The proper way is to renew all ties that need renewal, which means that every year two or three ties in each rail length will have to be renewed. Where the old ties have been cut by the rails, the rails must be raised by the new ties or the old bed cut down slightly to maintain the existing level. The Phila-

delphia & Reading Ry. specifically provides that ties must be removed only as they become unfit for service, in the manner known as spotting, and not in continuous sections.

Adzing Ties.

When ties have been badly cut by the rails, the rail seat must be cut level (or "spotted") with an adze, in order to form a proper bearing for the old or new rails, or for tie-plates. The trackmen have usually to rely upon their eyes in getting a level and even seat, and while practical men are very expert, yet as the ties are more or less covered with dirt and sand, and the men are hurried, the work is often imperfectly done. This is especially the case where an inferior class of labor is employed. In trimming ties preparatory to laying new rails, some roadmasters assign a few expert men exclusively to this work, as the ordinary laborers are apt to do insufficient adzing on hard ties and to cut too deeply in soft ties. Mr. G. M. Brown, when Chief Engineer of the Pere Marquette Ry., invented a machine for grooving the ties to the required depth, the grooves forming a gage or guide to the men in adzing the ties. A frame in front of a flat car, supported by an axle with 20-in. wheels, had a shaft with four sets of saws cutting four grooves about 2½ ins. wide. The depth of cut was regulated by a screw. The shaft was driven by an engine on the car. The end of the frame was suspended from a derrick on a car in front, to allow the saws to clear the rails at turnouts, etc. (See also "Change of Gage.")

Setting Tie-Plates.

In preparing to lay tie-plates on the Buffalo, Rochester & Pittsburg Ry., as many spikes are withdrawn and as much adzing is done as possible before the rails are moved. When the traffic permits, the rest of the spikes are withdrawn, the rails are thrown out, spike holes plugged, and seats adzed and leveled. The men work in gangs of three. One sets the gage and places the tie-plate in position. The other two have wooden mauls weighing 16 or 18 lbs., with ordinary spike-maul handles about 36 to 38 ins. long, to drive the plate down so that its flanges or claws will have a firm hold in the wood. When a sufficient number of plates have been thus set, one of the gangs can be sent back to throw in the rails and spike them, the spike holes in the plates giving the proper gage. A lighter maul may be used, if its face is large enough to cover the tie-plate, but some men prefer an even heavier maul. If the plates have longitudinal flanges, the first blow at least should be struck from a position at right angles to the flanges.

Considerable economy in track work may be insured by placing the plates on new ties for renewals before the ties are put in the track. This can be done by the section men in bad weather or during the winter. In using the tool, Fig. 179, for this purpose, the adjustable head, C, is clamped in such a position on the bar that tie-plates of the size to be used will be in position for the proper gage of track when they are set with their ends butting against the faces F and G. When set in this way, the flat blades of the two heads will fit on the seats for the tie-plates. The tool is then set on the tie to test the surface of the seats, and these are adzed or dressed as required to give an even and level bearing. The tool is then turned over and set with the faces F and G resting on the tie. One tie-plate is put in position, being gaged and squared by fitting against the face F and the blade B. This plate is

then driven down by means of the wooden mauls. The tool is put back in the same position, fitting against the plate, and the second tie-plate is then placed and set in the same way. The tool is frequently used for testing the level and surface of the rail seats of the ties when tie-plates are not to be used. The several operations are effected easily and rapidly. On the Boston & Maine Ry., the tie-plates are applied when the ties are on the track and ready for renewals. The tie is first tested as to face by a bar having flat plates to rest at the rail seats, and the tie is adzed until these have a true bearing. The tie-plate gage is then placed on the tie, with its center fitted to a center mark on the latter. The two tie-plates are set in rectangular frames at the ends of the gage, and on each one is set a 2-in. steel striking block 7¼×4¾ ins. These are struck with sledges.

Relaying Rails.

This work has been very fully described in Chapter 19. It is usually extra or special work, and not done in connection with the routine of track maintenance. The methods of unloading new rails and loading old rails on the track are described in the same chapter.

Shifting Rails on Curves.

On track having numerous sharp curves, the service of the rails may be extended by transposing the inner and outer rails. The rails are disconnected to form strings of about 600 ft. in length (disconnecting at the short rails on the inside of the curve). They can be moved lengthwise by bearing with bars against the ends of the angle bars, or by pulling with a locomotive. The inside spikes should be drawn, and in relaying to gage (on account of worn heads), the inner rail may be set in ¼-in., and the outer one ⅛-in., or according to the wear of the side of the head.

Bending Rails.

On all curves of over 2°, the rails should be bent to the proper curve before being laid. If they are laid straight and then merely bent by spiking, the curve will be irregular (especially at the rail ends), and the rails will have a constant tendency to straighten. Bending rails by springing or striking with sledges or dropping them on blocks should never be permitted, as such methods are more likely to form kinks than a true curve, and are also liable to break or injure the rails. If no rail bender is available, a lever and curving hook may be used, as described under "Tools." The rail should be curved in a proper rail-bending machine, and care taken to have the uniform curve continued right to the ends of the rail, as it is often found that the work is done less carefully at the ends, with the result that a kink is formed at each joint. Where a roller rail-bending machine is used, some roads pass all rails through this, to bend the rails for curves and to take out any kinks or bends in rails for tangents. (See "Renewing Rails.") For tracklaying or extensive renewals of rails, the work can be more rapidly done by a power-operated machine at the division or material yard than on the track. Slight kinks in curved rails in the track may be detected by testing the curve with a cord (see "Lining Curves"), and then taken out by extra spiking. In curving the rails the middle ordinate of a 30-ft. rail will be almost exactly ¼-in. for each degree of curve. The side or quarter ordinates are always three-fourths of the middle

ordinate. Table No. 28 gives a list of middle ordinates for different lengths of rails and different degrees of curvature, varying by $\frac{1}{8}$-in. The Southern Pacific Ry. and some other roads use tables varying by $\frac{1}{16}$-in. The middle ordinate (M) of a 30-ft. rail, the quarter ordinates (R) of a 30-ft. rail, and the middle ordinate (S) of a rail of any other length (T) may be obtained by the following formulas:

$$M = 0.02 \times \text{Degree of Curve.} \quad R = M \times 0.75. \quad S = M \times \left(\frac{T}{30}\right)^2.$$

TABLE NO. 28.—MIDDLE ORDINATES FOR CURVING RAILS.

Degree of curve.	Length of rails (feet).											
	10.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30.	33.
	Middle ordinates (inches).											
1/2	..	..	..	...	...	...	...	...	...	...	1/8	1/8
1	..	..	..	...	...	...	...	1/8	1/8	1/8	1/4	1/4
1 1/2	..	..	..	...	1/8	1/8	1/8	1/8	1/4	1/4	3/8	3/8
2	..	..	1/8	1/8	1/8	1/8	1/4	1/4	3/8	3/8	3/8	5/8
2 1/2	..	..	1/8	1/8	1/4	1/4	1/4	3/8	3/8	1/2	1/2	3/4
3	..	1/8	1/8	1/8	1/4	1/4	3/8	1/2	1/2	5/8	5/8	7/8
3 1/2	..	1/8	1/8	1/4	1/4	3/8	3/8	1/2	5/8	3/4	7/8	1
4	1/8	1/8	1/8	1/4	3/8	3/8	1/2	5/8	3/4	7/8	1	1 1/8
4 1/2	1/8	1/8	1/4	1/4	3/8	1/2	1/2	5/8	3/4	7/8	1	1 1/4
5	1/8	1/8	1/4	3/8	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 3/8
5 1/2	1/8	1/4	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 5/8
6	1/8	1/4	3/8	3/8	1/2	5/8	3/4	7/8	1 1/8	1 1/4	1 3/8	1 3/4
6 1/2	1/8	1/4	3/8	1/2	1/2	3/4	7/8	1	1 1/8	1 3/8	1 1/2	1 7/8
7	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 5/8	2
7 1/2	1/8	1/4	3/8	1/2	5/8	3/4	1	1 1/8	1 3/8	1 1/2	1 3/4	2 1/8
8	1/4	1/4	3/8	1/2	3/4	7/8	1	1 1/4	1 3/8	1 5/8	1 7/8	2 1/4
8 1/2	1/4	3/8	3/8	5/8	3/4	7/8	1 1/8	1 1/4	1 1/2	1 3/4	2	2 3/8
9	1/4	3/8	1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	1 7/8	2 1/8	2 1/2
9 1/2	1/4	3/8	1/2	5/8	3/4	1	1 1/4	1 3/8	1 3/4	2	2 1/4	2 3/4
10	1/4	3/8	1/2	5/8	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/8	2 7/8
10 1/2	1/4	3/8	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	1 7/8	2 1/8	2 1/2	3
11	1/4	3/8	5/8	3/4	1	1 1/8	1 3/8	1 5/8	2	2 1/4	2 5/8	3 1/8
11 1/2	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	1 3/4	2 1/8	2 3/8	2 1/4	3 1/4
12	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	1 7/8	2 1/8	2 1/2	2 7/8	3 3/8
12 1/2	3/8	1/2	5/8	7/8	1 1/8	1 3/8	1 5/8	2	2 1/4	2 5/8	3	3 5/8
13	3/8	1/2	5/8	7/8	1 1/8	1 3/8	1 5/8	2	2 1/4	2 5/8	3	3 3/4
13 1/2	3/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2 1/8	2 1/8	2 3/4	3 1/8	3 7/8
14	3/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2 1/8	2 1/2	2 7/8	3 1/4	4
14 1/2	3/8	5/8	3/4	1	1 1/4	1 5/8	1 7/8	2 1/4	2 5/8	3	3 3/8	4 1/8
15	3/8	5/8	3/4	1	1 1/4	1 5/8	1 7/8	2 1/4	2 5/8	3 1/8	3 1/2	4 1/4
15 1/2	3/8	5/8	7/8	1 1/8	1 3/8	1 5/8	2	2 1/8	2 7/8	3 1/4	3 5/8	4 3/8
16	3/8	5/8	7/8	1 1/8	1 3/8	1 5/8	2	2 1/8	2 7/8	3 1/4	3 3/4	4 5/8

30-ft. rail: 17°, 4 ins.; 18°, 4 1/4 ins.; 19°, 4 1/2 ins.; 20°, 4 9/16 ins.

Cutting Rails.

Where much cutting is to be done, as in fitting switch work, etc., a hack saw or portable track saw should be used. When a rail must be cut on the track, a common practice is to nick it all round with a cold chisel and then to lift up the end of the rail and drop it so that the nicked part will strike upon the cutting block, a tie, or a piece of rail. This is a most improper way to treat steel rails, and is likely to result in a rough end or a kinked, split, or even broken rail. It is also dangerous to the men. A better plan is to mark all round the rail with a chisel, then lay the rail along the ties, holding one end down with a tie and putting the cutting block underneath, 4 or 5 ft. back from the cut. A bar is then placed across the rail at a point ahead of the cut, one of the track rails being used as a fulcrum and one man bearing hard down upon the bar. Another man then holds the chisel in the cut at the bottom of the web (or lower fillet), while a third man strikes the chisel a sharp blow with a hammer or sledge. If the rail does not promptly break, the chisel may be held on the other side of the rail for a second blow. The rail should be carefully measured for the exact position of the cut, and a pencil line ruled as a guide for

the chisel, so that the cut may be made neatly and cleanly at the required place. The chisels should be sharp, and a deep cut should be made. It is a good plan to cut across the top of the head with a hack saw. Short pieces may then be broken off by striking with a sledge, but for longer pieces a rail bender may be used at the chisel cut. In any case the rail should be straightened after being cut, as it is likely to be kinked in the operation. The edges of the head should also be filed if necessary to make a neat and smooth joint.

Spiking.

All main tracks should have at least four spikes in every tie, the two outer spikes being nearer one edge of the tie (on double track this should be the side first struck by the train), and the two inner spikes near the other edge. None of the spikes should be less than 2½ ins. from the edge of the tie. This arrangement is designed to hold the tie square with the track and prevent slewing, but is a practical detail not infrequently neglected, the spikes being often placed in line across the tie. Double spiking is sometimes required on curves where rail braces or tie-plates are not available, the extra spikes being required on the outside to resist the lateral thrust from the wheels. Spikes should not be driven until the ties are in position, properly spaced, and square across the track. If this is not attended to, the spikes will not hold the rail properly when the ties are shifted to position. The tie should be supported by bars while the spikes are being driven, but should not be lifted from its bed. Too often, however, one or two men hold up the tie so as to raise it while the spike is driven, so that the tie then hangs from the rail by the spike. In spiking new rails they should be adjusted to position by a track gage, while enough spikes are driven to secure them.

The spiking should be done carefully, each spike being set vertically and driven straight down, with its shank touching the edge of the rail base. The spiker should bring the maul down with a long swinging stroke, striking squarely on the head of the spike, and keeping his hands well down, so that the handle of the maul will be approximately horizontal. He should not set the spike sloping from or towards him, as it reduces the hold of the spike head on the rail, while the head may very likely be broken by the last blow of the maul, and the spike will be bent by being pulled out. The spike should not be set a little distance from the rail and then struck on the back to drive it sideways into position, as this will enlarge the hole in the tie, weakening the hold on the spike and forming an entrance for water and moisture to rot the interior of the tie. Neither should it be driven slanting to or from the rail, for the purpose of tightening or widening the gage, but the rail should be thrown to line with a bar and then properly spiked. The last blow on the spike should be struck lightly, so as to avoid breaking the head of the spike when it comes to a bearing on the rail. At joints, the spikes should be driven in the slots of the angle bars, except on bridges, where free play is usually allowed for any creeping of the track, so as to avoid strains on the structure or its floor system. In warm weather, the spike should be driven against that side of the slot farthest from the end of the rail, thus allowing for contraction of the rail in colder weather.

In pulling spikes, care should be taken not to bend or break them, loosening tight spikes by giving them a tap on the head before applying the claw-bar. When old spikes are drawn, the holes should be filled with wooden plugs.

Long spikes should be used where thick shims are placed between the rail and the tie, and used also for fastening road crossing planks to the ties. The section men and trackwalkers keep continual watch of the spikes, but it is a good plan to send two men over each section, twice a year, to drive down every spike. They also replace all spikes which are broken, are not snug against the edge of the rail, or are not in proper position in the slots of the angle bars.

Bolting.

Rail joints should have the bolts screwed up tight as soon as put on, with nut locks or washers in place, but the bolts will usually have to be gone over again and tightened up with a wrench in a few weeks. The men should not put long handles on the wrenches. With this increase in leverage, careless men may stretch or strip the threads of the bolt or nut, so that the tightness and security of the joint will be impaired, even if the bolts are not made entirely useless. A strong, firm pull on an ordinary wrench is all that is required. The nuts should be slackened and retightened in the spring (before warm weather), and in the autumn (before cold weather), so as to insure proper freedom for the expansion and contraction of the rails. If held too tight, the rails may shear the bolts or buckle the track. All broken or damaged bolts should be replaced at once, and each joint kept fully bolted and fitted with the proper nuts, washers or nut locks. In removing bolts, while too much time should not be lost in trying to get off a rusty nut, care should be taken to see that the men do not get in the habit of saving time and trouble at the expense of damaging good bolts by knocking off the nuts and ends of bolts with a hammer, thus rendering both nut and bolt good only for scrap. If the bolts are comparatively new, the nuts may be loosened by tapping and the use of oil. When the nut has been taken off and the bolt removed, the nut should be screwed on the bolt to prevent loss. The nut and bolt should be thrown into a box or keg, and not left lying in the ballast. In some cases heavy clamps are used to force the splice bars into place instead of relying on the bolting for this.

Shimming

When the ballast is frozen it cannot be tamped, and if the track is heaved by frost, the surface is made uneven both transversely and longitudinally. This must be tested by a level for the former and by sighting or the use of a long straight-edge for the latter. Wooden plates or shims must then be placed on the low ties, to bring the rail up to proper surface. The upper face of the tie should not be adzed to lower the rail, unless this is absolutely necessary, but the shims should be placed on the lower ties. Shimming is also required with ballast which is so soft after heavy rains that tamping cannot be done, the ballast and roadbed being so saturated that no other method of surfacing is practicable. In some very bad cases, or in accidents, blocking must be used under the ties, but this should be avoided when possible. The foreman must see that the blocking is not forgotten and left in place, but that it is taken out when the shims are removed, or when the ballast has dried out sufficiently to give the track a proper bearing. As the frost comes out of the ground and the ground settles, thinner shims must be substituted for the thicker ones, to prevent surface bending of the rails. The shims should never be left in place after the spring, and as fast as they are removed the extra spike holes in the ties should be properly plugged.

The shims may be cut by the section men, but it is better to use those cut by machinery at lumber mills or the car shops, and having two spike holes bored diagonally opposite one another. They are about 6 ins. wide, and the length should be at least 18 ins., so as to give ample room for spiking and keeping the spikes clear of the angle-bars. The thickness is from ¼-in. to 2 ins., and long spikes must be used for those over 1 in. thick. If a raise of more than 2 ins. is required, a piece of 1-in. to 3-in. plank should first be spiked to the tie by boat spikes, the plank being about 2 ft. long, or as long as the tie if both rails have to be shimmed. Upon this plank should be placed shims to bring the rail to the required level, these being fastened by long spikes passing through shims and plank into the tie. In some cases, every shim is the full length of the tie, except where the rails are out of level. With a lift of 2 ins. or over, the shim should be long enough to carry a rail brace. If it is short, a hardwood block or a piece of plank may be used as a brace, having one end resting on the tie (and backed by spikes) and the other end wedged firmly against the web of the rail. A long spike is then driven close to the rail head, passing through the brace and shim. This bracing of the rails is especially necessary on curves. Where tie-plates are used, the plates must not be taken off, but the shims placed on them. If the shimming is high, a tie-plate may be placed on its top. The tie should be adzed to give a level seat for the shims. Spiking should be attended to as fast as the shimming is put in, and if a whole rail length is to be shimmed, the joint, center and quarter ties should first be shimmed and spiked. Where the trouble occurs continually, the ties will soon be damaged by the excessive spiking and respiking. The Central Ry. of New Jersey uses 7-in. spikes, ¾-in. square under the head and ⅝-in. in the body.

Shimming is but a makeshift way of providing a practicable and safe track under conditions that should not be allowed to exist on well-built railways (and should be remedied permanently). Nevertheless, it is required more or less on nearly every railway, and often where heavy traffic is carried. Even if not required on the main track, it may be necessary with the lighter construction of branches and sidings. The proper remedies are drainage, the replacing of saturated or otherwise bad material with cinders, slag, or gravel, and the application of a heavy bed of good ballast. Under unfavorable conditions of ballast and roadbed, a heavy frost may raise the track as much as 3 ins. in one night, and the heaving will not be regular or uniform. In severe cases, a second tie on top of the original tie is sometimes required. Although the work is temporary it must be done with great care to insure safety to traffic. The shims should be well placed and secured; the rails well spiked and braced; and proper run-offs provided so that trains may ride easily in passing from the unaffected track to the heaved and shimmed track. The work must also be carefully watched, as the heaving and subsequent settlement are uncertain and irregular. A cold night may cause excessive heaving, while on a warm sunny day the track may drop to its old level.

Moving Track.

In building additional tracks or improving alinement, it may be desirable or necessary to shift the existing track to another part of the roadbed. This may be done in either of three ways: (1) Tearing up the track and relaying it on the new location; (2) Sliding the track bodily in sections; and (3) Throwing the track with bars or by machine. Considerable work of this kind

has been done in the four-tracking of the New York, New Haven & Hartford Ry. In one place, where the new roadbed was 6 to 9 ft. above the old one, the two old tracks were shifted bodily 20 or 30 ft. on skids to the new roadbed, the old bed being then raised by filling to correspond with the new grade. The length of this stretch of track was 8,930 ft., including two bridges, at which the track had to be cut. On the open line, the track was cut at lengths of five rails by unbolting the splices. Planks were spiked along the ties to keep them properly spaced, and each length of track was then slid laterally on six skids made of rails spiked to stringers, 6×8 ins. The force aggregated 260 men, distributed as follows: A foreman with 35 men first raised the tracks ready for skids (using six jacks to a five-rail length), and drew all spikes from worthless ties, so as to leave them behind and avoid handling useless material. A foreman with 150 men then moved the lengths of track by block and tackle to the top of the new bank, unloaded ballast and roughly surfaced the track. A foreman with 75 men then made the connections between the lengths, and lined and surfaced the track. A work train ran back and forth distributing material. The skidding and lifting by the second gang averaged about three minutes per length of track. Work was commenced at 7 a.m., and the track was turned over to the operating department by 5 p.m. The second track was afterwards moved in the same way. The initial cuts were made where the new bank was only 2 ft. above the old bank, and the end pieces of track between the undisturbed track and the first lengths to be moved were thrown to the new alinement by lining bars. In some cases, owing to the curves and bridges, some of the five-rail lengths had to be moved longitudinally, even as much as 3 ft. For this purpose the skidding gang of 150 men had 75 bars; these were placed horizontally under the rails and held by a man at each end of each bar. The section of track was thus readily raised and moved forward or backward by easy movements. The lengths on the bridges were left until the last, the spikes being then drawn and the rails carried over and spiked to the floors of the new structures.

Under ordinary methods, the spikes would have been drawn, rail joints disconnected, and ties and rails carried about 25 ft. and relaid in the new position, as in new tracklaying. This would involve much more delay, and some considerable loss and breakage of bolts and spikes, though this might, of course, be reduced by carefully planning and laying out the work, in the same way as was done for the "skidding" method. On the other hand, the skidding is likely to result in surface or line kinks in the rails, bent splices, and displaced spikes, making it difficult to put the track in proper condition for service in its new location. If the track is for only temporary use, or for work trains, as on parts of the work above described, the skidding method may be adopted to advantage. For permanent work it would generally be better to build the new tracks complete in the usual way, then make connections with the old tracks at the ends, and abandon the old tracks, which can then be removed and the roadbed improved or rectified as required. In grade revision and track-elevation work, sections of track on the old level are sometimes tilted up on the ends of their ties and then pulled up the bank to the new position by derrick cars and cables (see "Permanent Improvements").

It is sometimes considered that for a short move it is most economical to throw the track by means of lining bars. Stakes should be set for the new alinement, and driven so as to be below the base of rails. The length of rails

on the new and old alinement should then be carefully measured with a steel tape, so that rails may be cut to fit if there is any difference. The new grade should be leveled and ballasted, the ballast being given an incline on curves, so that when the track is thrown it may be at once ready for traffic. If the track is to be thrown for a distance less than the length of a tie, then the part of the old roadbed which will be included in the new bed should be dug out below the ties. If the distance is greater, this need not be done, but the ballast should be loosened between the ties. Where the rails are cut, there should be six men (three cutting and three drilling). Having first disconnected the rails and removed the spikes on the side opposite to that towards which the track is to be thrown, two or three gangs, working one behind the other, should throw the track. They should not move it more than 12 ins. at each throw, so as to avoid bending rails and splice bars or twisting the ties. Other gangs should follow with the lining and surfacing as soon as the first part of the track is in its new position, but before the tamping is done, two or four men with sledges should tap the ties to proper spacing and square with the rails. Trains should be flagged to pass slowly over the new track until it is thoroughly finished and in substantial condition. The work may be done at once, in a time of light traffic, or gradually (between trains) during the week, proper curve connections being maintained at each end and all trains being flagged.

Track-throwing machines may be used where there is much work of this kind to be done. The Bierd machine used on the Panama Ry. resembles a self-propelling railway derrick car with a 35-ft. lifting boom moving in a vertical plane, and a 28-ft. shifting boom moving in a horizontal plane. A chain sling on the hoisting tackle is hooked to both rails and the track slightly lifted. The cable from the shifting boom has a hook which is attached to the inner rail, and as this boom is swung it throws the track bodily. The movements are made at intervals of 15 ft., or two to each rail length, and the track can be moved 4 ft. without injury. For a greater throw, the machine runs over the track again, but the lifting is only necessary for the first move. This machine is used in throwing track for double tracking and straightening; also, in shifting the tracks on the dumping grounds for the cars from the canal excavation. The Creese machine is a heavy flat car with a stout 30-ft. pole projecting from one corner and carrying a wheel which runs against the web of the opposite rail. The pole is adjusted to position by a cable and turnbuckles, and is stiffened by braces against the car. It can throw or shift the track 6 to 36 ins. This machine has been used on the Pennsylvania Lines and the Baltimore & Ohio Ry. Switches, frogs and crossings can be shifted on skids by gangs of men with bars; or by a locomotive and rope. Derrick cars can also be used for work of this kind.

Fencing.

On new construction the fencing is very generally done by contract, the railway company delivering the material loaded on cars to be distributed as required, and its engineers setting stakes for line and corners. The work may be done by a gang of 20 to 50 men, depending upon the character of the fence, the nature of the ground, and the speed required. Along existing lines the erection of new fences or the reconstruction of old fences is generally done by special gangs. The section gangs have only to do ordinary repairs on the fences or to build small lengths of fence. On the Cleveland, Cincinnati, Chi-

cago & St. Louis Ry., each division has from one to four gangs (about 4 men to a gang) to do nothing else but build and repair right-of-way fences and repair wing fences. The posts and wire are distributed by local freight trains. On new construction, where the fence work is very important, the materials are handled by work trains. The standard fence has posts 20 ft. apart, with 31½-in. woven-wire fencing and two strands of barbed wire at the top. On the Grand Rapids & Indiana Ry., a regular fence gang of a foreman and 6 men is employed for about six months of the year, being paid by the hour. The gang can build about a mile of woven-wire fence per week (420 hours).

The Louisville & Nashville Ry. has on each division a fence gang of from 6 to 10 men. With 55-in. woven-wire fence and posts 18 ft. c. to c., the cost of erection is from 2¼ to 2¾ cts. per lin. ft. In setting fences, the distance from the center of the track may be measured by a tape, and the line given by a cord or chain 100 ft. or 200 ft. long, having tags at the post spacing. When this is stretched, a small hole is cut at each tag as a mark for the post hole men. On curves, the position of each post may be measured from the center of the track by two men with a tape or cord, a mark being made or stake set for the post. For strand-wire fencing, posts (temporarily braced) may be set at intervals of 40 to 80 rods (660 to 1,320 ft.), and one wire stretched as a guide for the intermediate posts. The painting or posting of advertisements on board fences is objectionable, and should be prohibited.

Strand wire is delivered in rolls, and may be laid by placing the roll on a vertical revolving drum on a wheelbarrow or truck. The wires are attached to a straining post and set up by a stretcher, but in the absence of this tool a lining bar may be used, placed diagonally, with the top inclined towards the anchor post, and the wire being looped around the bar. In summer the wires must not be drawn too tight. Woven-wire fencing is delivered in rolls of 20 to 40 rods, weighing 10 to 16 lbs. per rod. The fence is unrolled flat upon the ground, with the bottom wire against the posts. The end is then lifted up, and with the stay wire vertical the line wires are bent around the end post, being well stapled at the back of the post so as to hold the fence securely. The fence is then raised to a vertical position, being held temporarily by staples lightly driven. When the other end is reached, the stretching tool is used to pull the fence tight. It is then permanently secured by staples on the posts, but these must not be driven so as to grip the wire, it being necessary to allow the line wires to move freely in expansion and contraction. In low spots, the bottom wire should be stapled to the bottom of the post; and at high points the top wire stapled to the top of the post, allowing free movement for stretching in either case. With board fences, the alternate posts may be set 16½ ft. apart, and a line of boards nailed along them will serve as a guide for lining the intermediate posts. The boards should be on the farm side of the posts. The materials and labor per mile for a four-board fence with posts 8 ft. apart, and a five-wire-strand fence with posts 16½ ft. apart, are about as follows:

Board Fence.

660 posts.
1,320 boards, 1×6 ins., 16 ft. long, 10,560 ft. B. M.
660 battens, 1×6 ins., 4 ft. long, 1,320 ft. B. M.
250 lbs. nails.
65 days labor for one man.

Strand-Wire Fence.

330 posts.
26,400 ft. of wire at 340 lbs. per strand, 2,200 lbs.
75 lbs. staples.
27 days labor for one man.

Clearing Right-of-Way.

All grasses, weeds and brush on the right-of-way and under trestles should be cut at least once a year, and preferably twice a year. This should be done in the months which are most suitable (according to the latitude), and before the seeding time of the plants in the autumn. This is not always practicable, however, as at that time labor may be scarce. After the grubbing, cutting and mowing, the material should be raked into heaps and burned as soon as it is dry. Old ties, splice bars, tools, etc., found during this clearing up should be properly disposed of. The mowing and cutting are sometimes omitted, the right-of-way being cleared by burning, sometimes not until after the early frosts. In this case, as well as in burning piles of brush, care must be taken to keep the fire under control (avoiding such work in windy weather) so that it does not spread to fields, fences or bridges. The foreman must see that it is thoroughly extinguished when the men leave work each day. If the brush on the right-of-way is allowed to grow too long, it is liable to catch fire in dry weather, such a fire being hard to check or stop. Reports of locomotives which throw sparks badly, and of fires started by sparks from locomotives, should be made by the section foremen and roadmasters. The spark arresters of locomotives should be examined frequently in hot, dry weather, when standing crops, weeds on the right-of-way, etc., are liable to catch fire. Where the right-of-way is covered with good grass, this may be mowed and used or sold for hay under the direction of the roadmaster.

Clearing and Burning Weeds.

The grass and weeds in the ballast and along the sides of the roadbed must be cut and killed periodically. The Southern Pacific Ry. requires that during the grass-growing season only so much grass and weeds must be removed as is absolutely necessary to keep the rails clear. At the end of that season the grass must be cut accurately to sod lines and the roadbed then kept clear between these lines until the beginning of the next growing season. On many railways where inferior ballast is used and the section gangs are small, this work is very troublesome and expensive, especially as the work should be done in the autumn, when it is hard to get a sufficient force of labor and there is other work to be done. This is particularly the case on prairie lines. The work is necessary not only for appearance, but to keep the rails clear and to prevent fires. It may have to be done three or four times in a season.

On parts of the Atchison, Topeka & Santa Fé Ry., with earth ballast, the heavy growth of grass and weeds is cut with light steel shovels every six weeks for about six months. It is cut only between the ties outside the rails, and as far inside as can be reached with a shovel slipped under the rail. This costs $7.50 per mile each time. In October, the grass is cut clean both inside and outside the rails at a cost of about $12.50 per mile. The total cost is about $35 per mile per year. On some prairie lines the cost is as high as $50 per mile per year, including cutting to a grass line 7 ft. from the rail. It is tedious and tiring work, especially with shovels. The men can work more conveniently with sharp, long-handled scuffle hoes, and with this tool one man can scurf or clean about 500 ft. of track in a day. The sprinkling of common salt (one barrel to 600 or 800 ft.) has been found effective, the work being done on a rainy day. The weeding should be done between "grass lines" 7 ft. or 8 ft. from each rail. The line may be set out by a cord and stakes. It

may also be marked by a cutter and plow handle on a bar parallel with the rails and hinged to a timber bolted across a hand car. The trimming outside the ties may be done by cutters on a ditching machine, as already described.

In order to reduce the trouble and expense of this work where conditions of vegetation and labor are unfavorable, various weed-killing machines have been introduced. One of these, tried on the Illinois Central Ry., had an electric generating plant supplying current to a "brush" of copper wires suspended across the track. Two trips were required, and while the treatment was effective, its cost was prohibitory for general work. Devices to divert the exhaust steam and gases from the smokebox of a locomotive by a pipe leading to a discharge nozzle across the track, have not proved satisfactory. Spraying with a strong solution of brine has been tried on the Oregon Short Line and other roads, but while it effectually kills the weeds, it has been found to cause (in some cases) a slime on the rails, which led to slipping of the engine wheels and corrosion of the rails. The rails can probably be protected by proper shields, however, as is done with the oil-spraying machines used to prevent dust on loose ballast. This application of oil also checks the growth of weeds. The Illinois Central Ry. has recently used a hot chemical solution (212° F.) sprayed upon the track from a car fitted with tanks and heaters and compressed-air apparatus supplying six nozzles. The composition is kept secret by the company handling it, but is said not to be dangerous to the men. The car can be run at a speed of about 10 miles an hour, and for ordinary growths a single application (with about 500 gals. per mile) is sufficient. A similar method has been used on the Guayaquil & Quito Ry., in Ecuador, where the luxuriant tropical vegetation required 1,600 gals. per mile, sprayed by steam or compressed air from a car run at a speed of 4 or 5 miles an hour. In this case, precautions had to be taken against poisoning, the solution being composed as follows: 1 lb. arsenical acid to 5 gals. of hot water, 1 lb. of nitrate to 6 gals. of water. The solutions are made separately in tanks having capacities in ratio of 5 to 6, and then mixed in a third tank ("Engineering News," March 2, 1905).

The method of burning weeds by the intense heat of oil or gasoline burners carried close to the track by special weed-burning cars has been employed on a number of roads, and has proved effective and economical. It was first introduced by the Minneapolis, St. Paul & Sault Ste. Marie Ry. about 12 years ago. Crude oil was then used, with a consumption of about 30 gals. per mile. The burners are just above the rails and the oil is sprayed by jets of steam or compressed air; an iron shield or pan diverts the flame and heat down upon the track. Side aprons extend outside the rails, and the burners and shields are carried by a frame which can be raised to clear crossings, bridges, etc. The machine used by the Atchison, Topeka & Santa Fé Ry. is a 50-ft. steel flat car with the necessary equipment, including two brake pumps to charge an air receiver at 70 lbs. pressure. A light crude oil is used, with a consumption of about 8 gals. per burner per mile. There are four burners and the shield spreads the flame to a width of about 10 ft. and a length of 15 ft. Any fire left in the track is extinguished by steam jets from the locomotive pushing the car, or by a gang of men following. The speed is 4 miles per hour, or 3 miles with thick coarse weeds. The cost of operation is $50 per day, and 20 to 30 miles can be covered, making $2.50 to $1.66 per mile. The Lamb machine, tried on the Illinois Central Ry., uses gasoline fuel, with 36 burners arranged

in two rows. The cost is estimated at $3 to $4 per mile for one trip, with $2 per mile extra if a second trip is required. The machine is run at a speed of 3 to 4 miles per hour.

In all the cases mentioned above, the machine is pushed over the track by a locomotive, but the Union Pacific Ry. is using self-propelling machines. A cast-steel bed plate forms the underframe, and is mounted on two axles. A gasoline engine is used, with a two-speed transmission gear; the machine is run at 3 to 6 miles an hour when at work, or 20 to 25 miles per hour when going to and from work. At one end are three cast-iron aprons, the outer ones being hinged so as to be swung up (parallel with the rails) to clear bridges or cattleguards, or lowered to conform to the slope of the ballast. The aprons cover a width of about 15 ft. There are 75 burners. The gasoline passes through pipes in the aprons, and in this way is vaporized so as to produce sufficient pressure to give a strong flame, compressed air being used only to force the gasoline out of the tanks. The machine is operated by an engineman, conductor and helper, and can burn over about 20 miles of track per day. It is found best to make two trips, as complete destruction at one trip would involve a slow rate of travel and a high fuel consumption, owing to the amount of water in the plants. If the weeds are subjected momentarily to an intense heat, the plant life is destroyed, so that they do not take any more water from the ground. After one or two days they will be dead and dry, and are then readily ignited and burned as the machine passes. About 20 gals. per mile is the average for each trip, with a total cost of $2.70 for fuel, wages, etc.; this makes $5.40 per mile for the completed work. On some roads a man follows on a velocipede to look out for ties that may have caught fire, but there is very little trouble of this kind.

Policing.

This work includes the general maintenance of the roadway in neat and proper condition, and is to be attended to continually. Weeds must be kept cut, and trimmed to the grass line; ballast properly sloped and dressed to a toe line; ditches cleaned; rubbish picked up, and spare material properly placed. Combustible material must be kept cleared from around bridges, trestles, signal posts, etc. Dirt and gravel must be removed from bridge seats and trestle caps, and care taken to prevent ballast from working over onto the bridge abutments or falling into streets below. Large loose stones may be neatly piled around the bases of signal posts, sign posts, etc., to keep vegetation from growing. All trees that are in danger of falling on the track, or that interfere with the passage of trains or obscure the view, must be removed or trimmed. If they are on private land, and the owner objects to such work, a report must be made as to the circumstances.

All old track material, material from cars, old ties, rubbish, etc., must be picked up and removed from the track, all scrap being carried to the section tool house to be sorted and properly disposed of. New material, such as rails, ties, etc., must be properly piled or stacked; no such material should be piled within 8 ft. of the track. Care should be taken to have a neat and tidy appearance of the section; with track full spiked and bolted; switches clean and well oiled; cattleguards and road crossings in good condition; fences in repair and wing fences at cattleguards kept whitewashed; ballast evenly and uniformly sloped and free from weeds, and sod line cleanly cut (usually

7 to 10 ft. from center of track or 12 ins. from ends of ties). Sidetracks and yards should be kept free from weeds and rubbish, old paper, scrap, etc. Station grounds also must be kept neat. Signs must be upright and in good repair. Section houses must be clean and tidy, with tools, track material, scrap, etc., properly sorted and placed. Some foremen will complain that they cannot do their work properly and spare time to keep the road looking neat, but it is very easy to do both if the men work systematically. It is much easier to keep the line neat than to have a periodical cleaning up at long intervals.

Means should be taken to keep people from walking along the track or using the railway as a public path. This is specially necessary near cities, where the traffic is heavy. In such cases, where people habitually walk on the track, a liberal covering of coarse broken stone or slag, or even cinders, may be laid upon the ballast between the rails and tracks and upon the berm at the edge of the roadway. Section foremen, crossing watchmen, etc., should order trespassers off the road. This matter is far too often neglected, and railways are themselves partly responsible in not checking the habit which the public has acquired of treating the track as a public way.

Station Grounds and Buildings.

In order to have a good reputation for the road on the part of the public, it is very desirable that the grounds at stations should be kept clean and tidy and free from rubbish. On some roads this work is delegated to the station agent, who has his men attend to it, and the Boston & Maine Ry. awards annual prizes to the agents having the most attractive grounds. As a rule, however, this is part of the section gang's work. The latter is the better plan if the force is sufficient, and if the work is done by direction of the roadmaster. The station agent should not be given authority to employ the section men for this purpose when he thinks proper. On roads making a feature of lawns and flower beds at stations, a special force is sometimes kept to attend to them. Many roads now employ landscape gardeners, and the Boston & Albany Ry. has on each of its principal divisions a gardener with 5 to 12 men, who grade, plant and seed the grounds, and take care of them. These men cut the grass with lawn mowers, and do the weeding, trimming of shrubbery, etc. They also attend to places where the banks are graded and seeded. This force is included in the roadway department. The Pennsylvania Ry. also employs landscape engineers and a force of gardeners in making and maintaining attractive grounds.

The Chicago & Northwestern Ry. has on its principal division a florist, with assistants to care for the flowers, etc. A greenhouse is provided. The station agents attend to watering the lawns, and the roadmaster details a man once a week to cut the grass. On the Michigan Central Ry., greenhouses and land for gardening are provided at Niles for the maintenance of station grounds on a division of 170 miles. The Atchison, Topeka & Santa Fé Ry. has a landscape gardener, and in some towns of the smaller class, the city authorities cooperate in this work, as it is to their interest to have an attractive appearance at the station. Many roads have adopted the policy of making "parks" at stations, sodding the ground and planting trees. It is specially desirable to have attractive grounds and pleasant surroundings at important stations and at junctions, where passengers may have to change trains or to stop over for connecting trains. Virginia creeper and Boston ivy make good creeping plants. Shrubbery is generally preferable to flowers, as the latter last so short

a time. The arrangement should not be too formal in design. The slopes of banks and cuts near stations may be covered with grass and kept trimmed.

In ordinary cases, however, much may be done by the foremen and station agents. The agent especially should see that the grounds and platforms are kept free from old papers and other rubbish. A plot of turf, cinder or gravel pathways, a flower bed, a creeper on the building or on a pile of rockwork, can be had with little trouble, and will have a good effect upon the general appearance of a station. The approaches and surroundings on the town side of the station should be cared for, as well as the grounds on the railway side. The platforms and fences should be kept in good repair. No hydrant pits, hose boxes, or other obstructions over which persons may stumble, should be allowed within the limits of passenger-train stops at stations.

The yards, spaces between tracks, etc., at stations should be neatly leveled and covered with ashes or gravel, and should be kept in order by the section gangs. Strict rules should be made and enforced against the scattering of ashes and cinders from engines (which should be dumped at specified points), and the sweeping of rubbish and dirt from the station or cars upon the track. Every station should have a can or bin for waste paper and rubbish, which should be emptied at intervals into a dirt car; similar receptacles should be provided at yards or places where cars are cleaned. At large terminal yards one man may be kept busy clearing up paper and rubbish. It is a good plan to have station inspectors to see that the stations, waiting rooms, closets, section boarding houses, etc., are kept in proper and sanitary condition, and that the grounds are properly cared for. Cleanliness and neatness should be enforced in every case, but the standard of appearance will, of course, vary according to the financial condition of the road and the size of the force.

Old Material.

In all renewals, and the periodical policing of track, cleaning up of yards, etc., it must be borne in mind that new material must be properly used and cared for, and not wasted, and also that no old material should be simply thrown away as useless. Even if really useless for railway purposes, the old material has a certain selling value, which is wrongfully lost to the company if the material is thrown away. These remarks apply also to the wreckage and scrap resulting from train accidents and the burning of cars. Record must be kept of the disposal of all scrap and old material. The roadmaster should examine the scrap occasionally, as a check upon men who may get in the habit of throwing away serviceable material and sending requisitions for new material that should not be needed.

Old rails should not be left hidden in the grass and weeds of the right-of-way, but properly piled for shipment, as they may be used for sidetracks or branches, sold for scrap, or even rerolled into "new rails" of somewhat lighter section. Old rails may be sorted into three classes: (1) Rails suitable for relaying in main line, which are usually only the best rails from tangents; (2) Rails suitable for sidetracks; (3) Scrap rails, or any which will not give 20 ft. suitable for sidetracks. Old ties have rarely much value, but if thrown away, sold, burnt, used for cribbing, etc., all unbroken spikes should first be pulled, and when ties are burned the ashes should be raked over for spikes. In piling old rails, the splice bars and bolts should all be removed, good splice bars sorted in pairs and broken bars kept separate. Nuts and bolts, if good,

should be kept together, but broken bolts should have the nuts removed and kept separate. Many spikes thrown away or put aside as scrap might be used over again if properly driven in the first place and properly drawn. Foremen should be careful to see that all track and car material, etc., is picked up regularly, and that their men do not get in the habit of flinging old bolts, spikes, etc., down the bank. In removing bolts, the nuts should be unscrewed properly, the bolt taken out, and the lock and nut put back on the bolt. If, however, the nut is so rusted or wedged on the bolt that it will not unscrew, it is more economical to knock off the nut with the end of the bolt in it, with a sledge, than to waste time in forcing the wrench. Only good discipline can insure the exercise of proper judgment as to when to knock off nuts in this way. Care should be taken not to hit the head of the rail.

At the section tool house the scrap should be sorted and piled (as described). This work, with the cleaning of serviceable scrap, removing nuts from broken bolts, etc., can be done in wet or stormy weather when the men cannot work on the track. All large pieces of iron or lumber must be neatly piled on platforms or sills. Car scrap, drawbars, couplers, etc., must be kept separate from track scrap. Brass scrap should be kept in a locked box. The scrap should be collected monthly by the store department, a car being sent out for this purpose. The general scrap pile at the shops may afford material available for use. Stub ends of ¾-in. to 1-in. bolts may be used for making track bolts in a bolt-heading machine equipped with suitable dies. Nuts may be compressed in the same machine and retapped. Plates and shapes may be used for various purposes, and old boiler tubes make good fence rails for station grounds or posts for fences and track signs. Rods, tubes, bars, etc., may also be available for reinforcing concrete. Splice bars may be sheared to length and stamped in a bulldozer to form rail braces. In some cases it may be economical to put in a set of small rolls to bring odd sizes of bars or rods to standard sizes for bolts, etc. A shear may also be used for cutting up rods. At the same time, articles made from scrap may be more expensive than new articles. Judgment and calculation will show how far this matter may be carried with economy. The scrap pile should be watched, and not allowed to form a receptacle for good or usable material.

CHAPTER 22.—GAGE, GRADES AND CURVES.

Gage.

The gage of track is the transverse distance between the inner sides of the rail heads. It should be measured at ½-in. or ⅝-in below the top of the heads, in order to clear worn corners and also to allow for rail heads having sloping sides. The gage of 4 ft. 8½ ins. is now practically universal or standard in this country. At one time there was a considerable mileage of 4 ft. 9 ins., but this has been mainly eliminated. It allowed undue side play of wheels set for the standard gage (especially at frogs and switches), and resulted in trouble from chipped wheel flanges and damaged guard rails, with consequent increase in cost of maintenance. In the early days of railway construction in this country, there was little uniformity as to gage of track, each line being

regarded as an individual and isolated enterprise, and nobody dreaming of the eventual linking up of the various lines into great connected systems, with interchange of traffic. In the northern states many railways were built to the English gage of 4 ft. 8½ ins.; the Camden & Amboy Ry. was 4 ft. 9 ins.; the Ohio gage was 4 ft. 10 ins., and various lines were of 5 ft. 6 ins. and 6 ft. gage. In the southern states, the usual gage was 5 ft., as recommended by Mr. Horatio Allen for the South Carolina Ry. As the principal lines were 4 ft. 8½ ins. gage, future development necessitated a change to effect uniformity, and on some of the broad gage lines this was effected by laying a third rail. In 1885 and 1886, several thousand miles of 5 ft. gage on southern railways were changed to 4 ft. 8½ ins. The narrow-gage craze is now a matter of history, and resulted in the building of several important lines of 3 ft. gage. Their isolation among standard-gage connecting roads, and the necessity for the through transportation of cars, led to these lines being changed, and it has been conclusively shown that there is practically no economy due to any but an extremely narrow gage. There are now no lines of more than 4 ft. 8½ ins. gage; but there are some short and local lines of 2 ft., 3 ft., and 3½ ft. gage.

The 4 ft. 8½ ins. gage originated in England, but the manner of its origin is somewhat indefinite. It seems probable that the old colliery wagons had a gage of 5 ft. over the wheels; flat rails and L-shaped rails (with the flanges sometimes inside and sometimes outside) were laid to carry these wagons. When edge rails and flange wheels were used, the width of 4 ft. 8½ ins. between rails was adopted to fit existing conditions of cars and track. A gage of 7 ft. was used by some railways, but with the growth of the railway system the necessity of uniformity became apparent, and the fierce rivalry (or the "battle of the gages") led to a Government inquiry in 1846; this resulted in the adoption of 4 ft. 8½ ins. as the standard gage. This is the standard for the greater part of Europe, but in Russia it is 5 ft.; in Ireland, 5 ft. 3 ins., and in Spain, 5 ft. 6 ins. Other countries have various standards, and have usually secondary lines of narrower gages, from 24 ins. to 42 ins. Thus in South America there are important lines of 5 ft. 6 ins., 5 ft. 3 ins., 4 ft. 8½ ins. and 3 ft. 3⅜ ins.; South Africa has 3 ft. 6 ins. as its standard, but various minor lines have narrower gages. India has important systems of 5 ft. 6 ins. and 3 ft. 3⅜ ins.; Japan, 3 ft. 6 ins.; China, 4 ft. 8½ ins.; Australia has 3 ft. 6 ins.. 4 ft. 8½ ins., and 5 ft. 3 ins. In fact, India and Australia have serious difficulties due to this multiplicity of gages, and the necessity of transferring freight and passengers at interchange points ("Engineering News," Nov. 15, 1906).

Change of Gage.

The work of changing broad gage lines to standard gage in this country has been described in the Journal of the Association of Engineering Societies, October, 1884; the Journal of the Western Society of Engineers, June, 1887; "Engineering News," Aug. 25, 1892; and the "Railroad Gazette," June 7, 1907. All this work has long been completed, but occasionally a piece of narrow gage has to be widened to standard gage ("Engineering News," Sept. 13, 1894). A piece of work of this kind was the widening of about 125 miles of 3 ft. gage by the Chicago, Burlington & Quincy Ry. in 1902. During previous years the bridges had been strengthened and widened, stations moved back, ties of standard size laid, and 66-lb. rails substituted for the lighter rails. The widening was effected by moving both rails 10¼ ins. outward. Before the change

was made, all ballast was leveled to about 1 in below the base of the rails, and old spikes or stubs at the new rail seats were removed. The rail seats were then spotted or trimmed by a machine similar to that already described under "Maintenance," and pushed over the line by a locomotive at the rate of 12 to 15 miles per day. A transverse shaft carried for each rail seat a group of four circular saws set diagonally so as to sweep over the entire space of 9 ins. between the outer saws After this, the outside spikes for each line of rails were partly driven in every third tie, the position being determined by a gage made of a bar of ½-in. iron, with one end bent up to rest against the web of the old rail, and having a handle on the flat part. The new spike was driven against the end of the bar. On the day before making the change the old spikes were removed, except five or six for each rail. About 500 section men were engaged for the actual changing of the rails in one day, and on the previous night or early in the morning, gangs of 16 to 20 men were distributed at intervals of four miles by narrow-gage trains. These gangs had ample tool equipment and each man was supplied with three lunches. Each gang also had a narrow-gage push car or hand car (distributed in advance) for carrying clothes, food and a water barrel. The spikes were removed, rails pushed out against the outer spikes already set, and new spikes driven. The work was completed in about 9 hours. All sidings and turnouts necessary for service were changed by the same gangs and at the same time. Less important sidings were left to be changed a few days later. Standard-gage trains followed the work and picked up the men as each section was completed.

Grades.

The maintenance work on grades may be increased very considerably if the traffic is heavy. This is owing largely to the increase in wear of rails resulting from the use of sand in ascending, and the application of the brakes in descending; and also to the general displacement and disturbance of the track, and the creeping of rails, all of which are aggravated on steep grades. In addition to maintaining good track on the grades, care must be taken to maintain the grades uniform at the prescribed rate. Surfacing and ballasting may result in breaking up the grade line by sags and high points in such a way as to materially increase the actual grade in places. For this reason, the engineer or roadmaster should occasionally run a line of levels over the division, especially on heavy grades, as any such changes in a maximum grade may have a serious effect in reducing the hauling capacity of the locomotives.

In view of the relatively high cost of maintenance-of-way, but more particularly the higher cost of operation, it is economy to keep the grades down as much as possible in construction, especially for heavy traffic. On the Erie Ry. great expense was incurred in order to keep the grades down to 1.14%. The South & Western Ry. was built (1906–1908) to give a direct route from the Virginia coal fields to the southeastern manufacturing districts and ports. Although it crosses the mountain ranges (instead of working around them), the maximum grade was limited to 0.5% against the heavy southbound traffic, and 1.2% for the lighter northbound traffic. On many railways the traffic has outgrown the original grade conditions; in such cases the roads are either operated at a disadvantage or great sums of money have been expended in grade revision (see "Permanent Improvements"). On the other hand, heavy grades may wisely be used for light traffic or for temporary use (as to avoid

the immediate construction of heavy permanent works), and also under special conditions where reduced train loads or assistant engines may be employed. The ruling grade is that which limits the maximum weight of train; it is not necessarily the maximum grade, as heavier engines or pusher engines may be used for the maximum train on the maximum grade.

Virtual or Momentum Grades.—Under certain conditions, the momentum stored in a moving train may be utilized to assist it in ascending a grade. For operation, the grade is virtually easier than the actual constructed grade. Momentum grades must be used with great care on new lines, and are rarely warranted as a means of saving in cost of construction. In such cases it might be a considerable time before the track and roadbed would be in condition to permit the speeds assumed in connection with momentum grades; in the operation of the line, therefore, what was assumed to be a momentum grade would be the actual ruling grade. Momentum grades are more applicable to and more generally used in improvement work and grade revision, and sometimes with a view to their elimination when traffic conditions require. Thus in the improvement of a division where grades were reduced from 1% to 0.6%, momentum grades were used freely, but the general grade line was so arranged that the momentum sections could be eliminated by raising the heights of embankments when financial and traffic conditions might warrant the expenditure. In some of these cases the momentum grade was continued to the last theoretical foot of height. In another case, the desired reduction of grades from 1.25% to 0.7% was found to be economically impossible; but by the use of 1% momentum grades the trains were successfully operated with the full tonnage for 0.7%. In planning the reduction of grades on the Ontario & Quebec Division of the Canadian Pacific Ry., in 1900, it was found that by the use of momentum grades, it would be necessary to reduce only about 30% of the original grades exceeding the new ruling grade of 0.6%, or to rebuild only 10% of the line. To reduce them all to the actual grade of 0.6% would have required the rebuilding of 30% of the line. With momentum grades, it is important not to include stopping points, severe curves, grade crossings and signals within the limits for acquiring and utilizing the momentum in the train; otherwise, a train may not be able to acquire the assumed momentum or to utilize it on the ascending grade, and may thus become stalled. This matter is discussed in works on railway location and in "Engineering News" of Nov. 22, 1900, and April 28, 1904.

Compensation of Grades for Curvature.—When curves occur on heavy grades, the grade should be so reduced that the combined train resistance due to grade and curve will not exceed that due to the maximum grade allowed on the tangent. This reduction is variously taken at 0.03 to 0.05% per degree. Thus with a maximum grade of 2% on tangents, and a rate of compensation of 0.04% per degree, the maximum grade on a curve of 6° would be 1.76%. The amount of elevation lost by compensating the grade is found by multiplying the degree of central angle of the curve by the rate of compensation, and this elevation divided by the length of grade will give the rate by which the tangent maximum must be increased to introduce the compensation without a final loss in elevation. The change in grade may commence at the nearest even station, and not necessarily at the P.C. or P.T. The reduced grade usually extends beyond the curve. To avoid too great a loss in elevation or too heavy a grade on the tangent, it may be necessary to modify the rate of com-

pensation, but this will depend largely upon traffic conditions. The compensation should in general be introduced even upon easy grades, especially those which approach the rate of ruling grade, in order to provide for future increase in train loads or reductions in grades. For curves of 10° or over, the rate of compensation may be reduced. A rule in general use at one time required an increase in compensation on sharp grades, but Wellington's "Economic Theory of Railway Location" (which gives perhaps the best exposition of this subject) shows that this was based upon the erroneous assumption that curve resistance increases with the degree of curve. On a curve immediately above a regular stopping place, the compensation may be 0.10%, to allow for trains that have not acquired speed. On a curve immediately below a stopping place, the rate may be reduced to about 0.03%, but in Prof. Webb's "Railway Construction" it is stated that no compensation need be used under such conditions, as the resistance due to the curve will correspondingly reduce the work required from the brakes in stopping a train. ("Engineering News," April 23 and June 11, 1908.)

There is a great diversity of practice, which is based largely upon opinion and experience, and there is much need for careful experiments in order to give some definite knowledge as to the requirements under modern conditions of rolling stock and traffic. On the Northern Pacific Ry., a compensation of 0.03% was found insufficient; 0.04% gave fairly good results, but was not quite sufficient with curvature frequently changing in direction, while on very long curves in one direction, the rate was somewhat in excess of requirements. This was noticeable only on long trains, and the condition of the cars had a good deal of influence upon it. The Illinois Central Ry. has adopted 0.04%, and increases this 0.1% at stopping places. On its Indianapolis Southern line, 0.04% was used when the length of curve was equal to that of the maximum train, and 0.03% when its length was not more than half that of the maximum train. On the Louisville & Nashville Ry., 0.03% has been found insufficient where a great many curves occur close together, and in future the compensation will be 0.05%. In compensating at stopping places, the practice is to reduce the grade 0.2% in addition to the compensation for curvature. On the Chicago, Milwaukee & St. Paul Ry., compensation for curvature on maximum grades is generally at the rate of 0.035%. In some cases this is reduced to 0.03%. It is not the practice to compensate for curvature near stopping places, but if such stops are on maximum grades, the grade is reduced 0.1% to 0.2%. On the Philadelphia & Reading Ry., the compensation is 0.04% per degree, and this applies also to stopping places. On the Canadian Pacific Ry., the compensation is 0.04% on ordinary work, but in tunnels this is increased to 0.06%, on account of the probability of damp rails.

Vertical Curves on Grades.

The angles formed by the junction of grade lines may be rounded off by vertical parabolic curves. The advantages of these in relation to the operation of train service are of greater importance at sags than at summits. The length recommended is 200 ft. on each side of the vertex. On the Northern Pacific Ry. the length was not less than 50 ft. for each change of 0.1% in rate of grade on summits, and 0.05% in sags. This made the curves 200 ft. long in sags for each change of 0.1% in grade. On the New York Central Ry., the length is 200 ft. for each 0.1% change in rate of grade where the average change

is about 0.5%, or 100 ft. where the average change is about 1%. On the Virginian Ry., vertical curves are used wherever there is a break of more than 0.2% in the grade line. The Illinois Central Ry. on new work uses vertical curves where the adverse grades are 0.25% or greater. They are from 400 ft. to 2,000 ft. in length, according to conditions and grades. The Louisville & Nashville Ry. uses them when the difference of the grades is 0.2% or more. The length at summits is half the change of grade (in tenths) multiplied by 100 ft.; at sags it is made equal to the change of grade (in tenths) multiplied by 100 ft. The Chicago, Milwaukee & St. Paul Ry. uses them at all breaks of grade where there is a variation of 0.3% or more. Generally a circular curve is used which will give a variation in the rate of grade of about 0.10 at summits and 0.05 at sags.

Corrections for grade elevations in laying out these curves, prepared by Prof. Nagle, were given in "Engineering News," Nov. 26, 1896, and Table No. 29 gives the vertical distance from grade line to curve at different points along the curve. The length of curve should be about 600 ft. at summits, and 800 to 1,200 ft. at sags. The curve chosen is a parabola, because of the ease with which any correction may be found when the correction at the vertex, or meeting point of grade lines, is known. Two properties of the parabola are utilized: (1) That ordinates from tangent to curve vary as the square of the distance from the point of tangency; and (2) That the curve bisects the vertical intercepted between the vertex and long chord joining the P.C. and P.T. In Fig. 207, HG (=T) is the correction at distance X from A; CD (=M) is the cor-

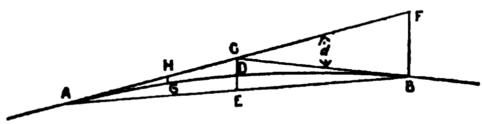


Fig. 207.—Vertical Curves for Grade Intersections.

rection at the vertex, and 2L is the length of the curve in stations; then the property first referred to gives the relation in formula (1).

To find M, produce AC to F to meet a vertical through B, the end of curve. Call the algebraic difference of grades d, then will FB = Ld, and since CD = ½CE by the second property, M = ¼FB, or M = ¼Ld. The length of curve, 2L, may be fixed by the circumstances of the case or may be found by assuming a certain rate of change of grade per station, the rate of change increasing with d. Call this rate of change R, then for L in stations the formula is (2). To find

$$(1)\quad T = M\frac{x^2}{L^2} \qquad (2)\quad L = \frac{d}{2R} \qquad (3)\quad T_1 = \tfrac{1}{2}\frac{L^2R}{L^2} = \tfrac{1}{2}R$$

the correction at a point one station distant from the P.C. at A, insert the value of d in the formula M = ¼Ld, and the resulting value for M in the first formula, x being one station; the result is in formula (3). At two stations from A, $T_2 = 2R$; at three stations, $T_3 = 4\tfrac{1}{2}R$; at half a station, $T_{\frac{1}{2}} = \tfrac{1}{8}R$, etc. Table No. 29 gives values of T for points 50 ft. apart for a few values of L and d. These corrections must be added when the algebraic difference of grades is minus, and subtracted when the algebraic difference is plus.

Curves.

A considerable proportion of the railway mileage is composed of curves, especially on lines where excessive curvature has been introduced through bad

location or to reduce the cost of construction. Curves are objectionable from both the operating and the maintenance standpoints, and it is particularly important to avoid or eliminate them on long ruling grades. The train resistance due to curves is higher at the ends of the curve, from the fact that in entering and leaving the curve the trucks have to be shifted to and from the radial position. This is the case even where transition or easement curves are used, and one advantage of improving the alinement is in reducing the number as well as the sharpness of the curves. The operating cost due to curvature is estimated to average $1 per degree of curvature per daily train per annum under ordinary conditions; this increases under conditions of heavy traffic and high speed, and for curves of over 3° to 5°. The cost of maintenance is increased on curves, owing to the increased wear of rails and the general disturbance of the track. It is estimated that each 12° of curvature per mile adds 1% to the cost of labor in surfacing and general maintenance work. Not only are the rails themselves worn, but the lateral pressures exerted by the wheels tend to slide the rails outward and also to overturn them (revolving on the outer edge of the base). This causes wear and necking of the outer spikes, the pulling up of the inner spikes, and a marked cutting of the ties under the outer edge of the rail. Tie-plates improve these conditions, but in general there will be continual respiking and redriving of old spikes. This again results in increased injury to the ties and a consequent reduction in life, and increase in material and work for tie renewals. The lateral pressure also tends to shift the track in the ballast. On curves, therefore, the maintenance work will be increased in nearly all its departments.

TABLE NO. 29.—CORRECTIONS FOR VERTICAL CURVES.

Algebraic difference of grades, per ct.	Rate of change per station, ft.	Horizontal distance from vertex in feet. 0.	50.	100.	150.	200.	250.	300.	350.	400.
		Vertical distance in feet.								
0.3	0.075	0.15	0.08	0.04	0.01	0	...	...	...	...
0.4	.1	.20	.11	.05	.01	0	...	...	...	...
0.5	.125	.25	.14	.06	.02	0	...	...	...	...
0.6	.15	.30	.17	.08	.02	0	...	...	...	...
0.7	.175	.35	.20	.09	.02	0	...	...	...	...
0.8	.20	.40	.23	.10	.03	0	...	...	...	...
0.9	.225	.45	.25	.11	.03	0	...	...	...	...
1.0	.25	.50	.28	.13	.03	0	...	...	...	...
1.1	0.1833	.83	.57	.37	.21	0.09	0.02	0	...	...
1.2	.20	.90	.63	.40	.23	.10	.03	0	...	...
1.3	.2167	.98	.68	.44	.24	.11	.03	0	...	...
1.4	.2333	1.05	.73	.47	.26	.12	.03	0	...	...
1.5	.25	1.13	.78	.50	.28	.13	.03	0	...	...
1.6	.2667	1.20	.83	.53	.30	.13	.03	0	...	...
1.7	.2833	1.28	.89	.57	.32	.14	.04	0	...	...
1.8	.30	1.35	.94	.60	.34	.15	.04	0	...	...
1.9	0.2375	1.90	1.46	1.07	.74	.48	.27	0.12	0.03	0
2.0	.25	2.00	1.53	1.13	.78	.50	.28	.13	.03	0
2.1	.2626	2.10	1.61	1.18	.82	.53	.30	.13	.03	0
2.2	.275	2.20	1.68	1.24	.86	.55	.31	.14	.03	0
2.3	.2875	2.30	1.76	1.29	.90	.58	.32	.14	.04	0
2.4	.3	2.40	1.84	1.35	.94	.60	.34	.15	.04	0
2.5	.3125	2.50	1.91	1.41	.97	.63	.35	.16	.04	0
2.6	.325	2.60	1.99	1.46	1.02	.65	.37	.16	.04	0

In passing around curves, the outer wheel has to travel a greater distance than the inner wheel in the same time, but as both are rigidly secured to the same axle, there can be no check to the rotation of either one. The result is that the outer wheel tends to slide ahead bodily, swinging from the inner wheel as a center and with the axle as a radius. With two axles in a truck frame, the truck tends to swing horizontally around the inner rear wheel as a center. The combined effect of the difference in length of path traveled

by the inner and outer wheels and the variation of the axles from a true radial position results in a lateral sliding of the inner wheels across the rail. Thus the flange of the outer wheel of the first axle of a truck bears against the outside rail, while the flange of the inner wheel of the second axle presses against the inside rail. The first tends to cut the outside rail, but the second merely presses against the inside rail. The greatest wear of the outside rail is on the side of the head, which has to guide the wheel flanges. The corner and side of the head gradually wear to conform to the section of wheel fillet and flange. The side therefore wears to a sloping face, and this wear becomes greater as the slope approaches that of the wheel flange. The inner rail does not get cut or worn in the same way, as the edge of the wheel flange runs from it instead of towards it, but the lateral slipping on top and lateral pressure against the side tend either to crush the metal so as to deform the head, or cause it to flow and form a lip or fin beyond the original line of the side of the head. This crushing and flow may also be caused in the outer rail. The use of locomotives with long rigid wheelbase increases the destructive effect, but it is in many cases aggravated by the failure of the car trucks to promptly swing to the radial position in entering curves. This may be the result of a stiff or heavily loaded center-bearing (causing the center plates to bind), or of a loaded car body bearing heavily on the side-bearing from its own dead weight or by its tilting as it enters the curve before the trucks have time to swing to their proper position. This holds the trucks in such position that the wheel flanges run hard against the outer rail.

Rails on curves may be double spiked, or (for curves of 4° and over) have braces on the outside to resist the lateral pressures already mentioned. The use of metal tie-plates is also important, as they prevent the cutting of the tie and make the inside and outside spikes act together. They, however, reduce the friction between the rail base and its support, and do not resist the lateral thrust of the rail base unless provided with shoulders. These appliances reduce the work of maintenance on curves. On heavy curves the gage may be maintained by the use of bridle rods or tie bars, holding the base of the rails like switch rods, there being from two to four bars to a rail length. These are very little used, however. On sharp curves, the gage should be widened, as noted farther on, and a guard rail is sometimes laid inside the inner rail to prevent derailment. A point to be considered in questions of widening gage, guard-rail space, minimum radius, etc., is the length of lap of the wheel flanges below the rail head, and this is given below, the flange depth being taken as 1⅛ ins.

Wheel diameter.	Lap.	Wheel diameter.	Lap.
30 to 34 ins.	12 ins.	54 to 60 ins.	16 ins.
35 " 40 "	13 "	61 " 68 "	17 "
41 " 46 "	14 "	69 " 76 "	18 "
47 " 53 "	15 "		

The curvature is not usually reckoned by the radius (except in the case of very sharp curves), but by the number of degrees of central angle subtended by a chord of 100 ft. The radius of a 1° curve with a 100-ft. chord is 5,730 ft. (or, more exactly, 5,729.65 ft.), and the radius (on center line) or the degree of any curve may be obtained by dividing 5,730 by the degree or radius respectively. In Fig. 208, diagram 204 shows the various nomenclatures used in curve work. The "central angle" (A) is the angle contained within the radial lines to the extremities of the curve, or the P.C. (point of curve) and P.T.

(point of tangent). The "degree of curve" (B) is the portion of the central angle which is contained within radial lines to a chord 100 ft. long on the curve. The "angle of intersection" (C) is the exterior angle at the intersection of the two tangents produced, and this angle is equal to the "central angle" (A). The "angle of deflection" (D) is the angle contained within the tangent produced and a 100-ft. chord on the curve. Taking X as the length of

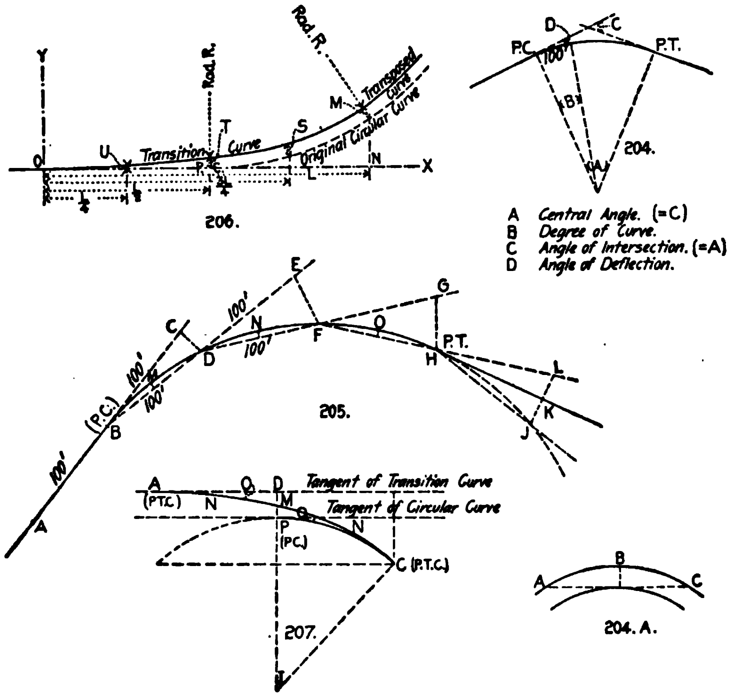


Fig. 208.—Curve Diagrams.

curve in feet, Y as the degree of curve, and Z as the central angle, the relations may be obtained by the following formulas:

$$(4)\ X = 100\frac{Z}{Y}. \qquad (5)\ Y = 100\frac{Z}{X}. \qquad (6)\ Z = \frac{YX}{100}.$$

Table No. 30 affords a handy means of ascertaining the degree of a curve in the track (see "Lining"). It is based upon that arc of the outer rail which is cut off by a chord tangent to the gage side of the inner rail, the middle ordinate being the gage of the track, as in Fig. 208 (diagram 204, A). The length of the arc may be measured by rail lengths on a short curve, or by feet on a long curve. To find the degree of the curve, stand at a joint on the outer rail and sight across the gage side of the inner rail to the outer rail. Then count the rails between these points, or measure the chord AC, or arc ABC, and the degree of curve will be found in the table. Methods of ascertaining the relative lengths of the inner and outer rails on curves are given under "Maintenance."

TABLE NO. 30.—CURVE FUNCTIONS.

Degree of curve.	Radius of center line, ft.	No. of 30-ft. rails in ABC.	Length of— Arc ABC, ft.	Length of— Chord AC, ft.	Central angle. Degs.	Central angle. Mins
1	5,730	15.5	463.5	463.4	4	38
2	2,865	11	328.6	328.4	6	34
3	1,910	9	268.1	267.9	8	02
4	1,433	8	232.5	232.2	9	17
5	1,146	7	208.0	207.7	10	24
6	955.4	6.3	190.0	189.7	11	22
7	819.0	5.8	175.8	175.5	12	16
8	716.8	5.5	164.8	164.5	13	08
9	637.3	5.2	155.2	154.8	13	54
10	573.7	4.9	147.5	147.1	14	40
11	521.7	4.6	140.6	140.1	15	22
12	478.3	4.5	134.8	134.3	16	04
13	441.7	4.3	129.5	129.0	16	42
14	410.3	4.1	124.8	124.3	17	20
15	383.1	4.0	120.6	120.1	17	56
16	359.3	3.9	116.8	116.3	18	30
17	338.3	3.8	113.3	112.8	19	04
18	319.6	3.7	110.3	109.8	19	38
19	302.9	3.6	107.4	106.8	20	10
20	287.9	3.5	104.7	104.1	20	40

For spurs and industrial branches, or temporary work, it is often convenient to lay out a curve without waiting for the use of an instrument, and in Fig. 208, diagram 205 shows how to set out a circular curve. The tangent approach is first carefully lined up and a stake, B, set at the P.C. and another, A, 100 ft. back on the tangent (both on center line of track). The tangent is then lined in for 100 ft. beyond the P.C. at A, giving point C. The 100-ft. tape or cord is then held by one end at A, while its other end is moved inward from C for the distance given in Table No. 26 as the tangent deflection on a chord of 100 ft. for a curve of the required degree. This gives point D on the curve, and a stake is set at this point. The chord AD is then extended to E, 100 ft. The tape being held at D, its free end is moved inward from E for the distance given in the table as the curve deflection on a chord of 100 ft. for a curve of the required degree. This gives another point F on the curve. The curve deflection EF, GH is always twice the tangent deflection CD, LK. The points H and J on the curve are set out in the same way from F and L. If the curve ends at H, as shown, then from the point L the tape will be swung in for the distance previously used for the tangent deflection CD, and this will give a point K on the tangent, 100 ft. from the P.T. at H. Intermediate points on the curve may be set out by measuring the middle ordinate for each 100-ft. chord, as given by the table, thus marking the points M, N, R. Table No. 31 gives the tangent offset CD (Fig. 208, diagram 205) for a tangent BC and chord BD, both 100 ft. long, and also the middle ordinate of a chord 100 ft. long, so that the table may be used in setting out curves by offsets or ordinates. In the former case it must be remembered that the curve offsets EF, GH, etc., are double the first or tangent offset.

In tracklaying, as well as in location, it is often desirable to ascertain the divergence of a curve from its tangent, and this is given by formula (7), prepared by Mr. Muenscher:

(7) $X = 0.875\ N^2D$. (Example) $0.875 \times 5^2 \times 6 = 131.25$ ft.

X is the offset, or distance of one end of a curve from a tangent passing through the other end; N is the length of the curve in chords of 100 ft.; and D is the degree of curvature. Thus the divergence of a curve of 6° from its tangent in a length of 500 ft. will be as shown. By making D equal to the difference

of the degree of curvature of two curves of different radius, but having a common origin, X will be their divergence from each other at the end of N stations. In tracklaying, if X = the gage of track, and D = the degree of curvature of a turnout track (or corresponding to a given number of frog), N will be the lead of the main track. If X is half the gage, N will be the lead of the crotch frog, and if X is the throw of a stub switch, N will be the free length of the switch rail. The formula is sufficiently accurate for practical purposes, and is of great use in field work, with the aid of a table of actual tangents for a 1° curve. For example, suppose a 5° curve to the right, 8 stations long, has been located, and its extremity falls 28 ft. too far to the right to throw the tangent on the best ground. Making $X = 28$ would give $D = \frac{1}{2}°$, showing that a 4° 30′ curve starting from the same origin would pass through the required spot. Suppose that in the same case the new curve is to commence 200 ft. back of the first one; then the required divergence from the tangent will be $0.875 \times 8^2 \times 5 - 28 = 252$. Substituting this value for X and making $N = 5 \times 2$ gives $D = 2.88 = 2° 53'$.

TABLE NO. 31.—CURVE OFFSETS AND ORDINATES.

Degree of curve, Deg.	Mins.	Tangent offset,* ft.	Middle ordinate, ft.	Middle ordinate, ins.	Degree of curve, Deg.	Mins.	Tangent offset,* ft.	Middle ordinate, ft.	Middle ordinate, ins.
1	0	0.873	0.218	2½	7	0	6.105	1.528	18¼
1	30	1.309	0.327	...	7	30	6.540	1.637	...
2	0	1.745	0.436	5¼	8	0	6.976	1.746	21
2	30	2.181	0.545	...	8	30	7.411	1.855	...
3	0	2.618	0.654	8	9	0	7.846	1.965	23½
3	30	3.054	0.763	...	9	30	8.281	2.074	...
4	0	3.490	0.872	10½	10	0	8.716	2.183	26¼
4	30	3.926	0.982	...	10	30	9.150	2.293	...
5	0	4.362	1.091	13	11	0	10.585	2.402	29
5	30	4.798	1.200	...	12	0	9.453	2.620	31½
6	0	5.234	1.309	15¾	15	0	13.053	3.277	39¼
6	30	5.669	1.418	...	20	0	17.365	4.374	52½

* The offsets around the curve are double the length of the first and last or tangent offsets.

Transition Curves.

One of the great difficulties in track work is to maintain an easy riding track at the connection of tangents with curves where circular curves spring directly from the tangents. This is especially the case where speeds are high. The cars will pass as easily and smoothly round a well-laid curve as along an equally well-laid tangent, but there is an unpleasant lurching at each end of the curve, due to the sudden change of direction from rectilinear to circular motion, and to the sudden change in position of the trucks, as already noted. The effect of this lurching is shown by the increased wear of the rails and disturbance of the track at this point, indicating that a lateral force is exerted which has to be resisted in guiding the train along the track. In very many cases an attempt is made to remedy this by some form of transition or easement curve connecting the tangent with the curve proper in such a way as to make the change gradually. Where a circular curve is laid out to start directly from a tangent, the foreman will usually shift the ends to make an easier riding track. This is done by throwing the track inward by means of lining bars, so that the curve is practically extended 100 ft. onto the original tangent. The curve is therefore flattened at this point, which is an advantage in giving an easy change from the tangent to the true curve. It is true that this necessarily sharpens the curve a little beyond the located P.C., but there the motion is felt less severely, as the car has already begun to change its direc-

tion. If this is not done by the section men, the traffic will slightly shift the track to the position giving it the easiest path (which is an objectionable means of obtaining a desirable end). The use of the transition curve throws the curve out on the tangent, or makes it longer, which is what the trackman does by rule of thumb, as above noted. The curve thus altered rides very much more easily, and it is probable that there are very few curves which are not, intentionally or otherwise, maintained in this condition to some extent. The curve should be laid out definitely and permanently, however, and not left to the arbitrary action of the section foreman.

In Wellington's "Economic Theory of Railway Location" the case is concisely stated as follows: "What is wanted is, (1) to ease off the curve by a rapidly changing radius for a short distance at the ends—a transition curve; and (2) to leave the great body of the curve of uniform radius." With such a curve the work of the trackmen will be considerably reduced, and there will be less wear of wheel flanges, rails and rolling stock. The transition may be effected in three ways: (1) By a compound curve, having at each end a curve of greater radius compounded with the main curve; (2) By compounding short circular arcs of gradually increasing radius, until the radius of the main central arc or curve is reached; or (3) By a spiral curve. The third system is in general the best. The Searles so-called spiral (which is of the second class, with arcs of equal length) and the Holbrook true spiral are both extensively used, and numerous other systems and modifications have been introduced by different engineers. A majority of the important railways employ transition systems of some kind, and in most cases these are based upon spiral curves. The objections that have been made usually against the use of transition curves are as follows: (1) The benefits are largely theoretical; (2) The practical effects are obviated by the variable velocity of the traffic; (3) The curves are more difficult to lay out and to maintain in alinement. The first objection can hardly be sustained in the face of extensive experience as to the practical advantages derived, and which are worth much more than they cost. As to the second, while it is true that the easement cannot be made to fit the variations of train velocity, it can be made to fit the prevailing velocity. This same objection would apply to the superelevation on curves, but no engineer would propose to dispense with superelevation. As to the third objection, the computation and field work of location are but little more difficult than for circular curves without easement. The location is easily made precise enough for all practical purposes, and the maintenance of alinement is no more difficult if the curve is properly and permanently marked. The rail wear and the maintenance work for alinement at curves will be much reduced on a track thus located, and the trackmen soon come to realize this in its relation to their work.

The use of transition curves has greatly increased within recent years, and new methods have been developed which are simple, practical and generally applicable. They can be adjusted to existing lines without excessive staking out or shifting of track. In most cases the length of transition is twice the length of the simple curve which it replaces, while its angle is the same as that of the simple curve which it replaces. Owing to the greater length of curves thus treated, in relocation, where reverse curves separated by short tangents occur, the tangents will be still further shortened. Absolute reverse curves cannot be so relocated without increasing the curvatures to get in the

necessary length for the transition between them, but such curves so transitioned are less objectionable than circular reverse curves of easier curvature and with short connecting tangents. As it is desirable to adapt the transition to traffic conditions, and as the superelevation of curves varies according to local conditions of speed and traffic, a method has been developed by which the length of transition is governed by the curve elevation (say 350 times the elevation). In relocating a circular curve to apply transition curves at the ends, the center line of the main part of the curve will be thrown inside the original center line. This would be a serious objection in applying transition curves to existing track, as it would necessitate an excessive amount of shifting of track and would result in closing up the rail joints. If the main curve is left in position, the tangents must be thrown out to meet the transition curves. To meet this condition, a method is used on the New York Central Ry. and other roads by which the original length of curve is maintained. The center portion of the curve is slightly sharpened, and moved a few inches outward. The ends are drawn a few inches inward, so that the transitioned curve intersects the old simple circular curve near the ends of the latter. In this way the improved curve can be placed on an existing roadbed where no great change in position is practicable.

In the location of the Virginian Ry., a transition curve was used which forms a spiral approximating to a parabolic arc, but the method of laying it out is simpler. It has twice the length of the circular arc which it replaces, though the angle subtended remains the same. The spiral curve is divided into as many stations as there are degrees in the curve for which it forms the approach, and the curvature increases 1° for each of these stations. By varying the length of the stations the spiral may be made as sharp or as easy as the tangent conditions will allow. This method leaves the tangent in its original position, while the center of the circular or main curve is drawn into the intersection angle. It is used for all curves of 2° and over on some parts of the line, and those of 5° and over on other parts. The St. Louis & San Francisco Ry. uses spirals on all main-line curves over 2½°. Half the spiral is on the original curve, and it is marked by a round stake at each end; a square stake marks the P.C. or P.T. of the original curve. On the South & Western Ry., the Sullivan system ("Engineering News," July 3, 1902) is used at the ends of all simple curves of 3° and over, and between the parts of compound curves which vary by 3° or more. The length is usually 200 ft. It is a parabola, with the same number of sub-chords as there are degrees in the curve to which it is applied; the spiral increases 1° for each sub-chord until at the end of the last sub-chord its curvature corresponds with that of the main curve. Transition curves are used for curves of 1° and over by the Philadelphia & Reading Ry. and Louisville & Nashville Ry.; and for curves of 2° and over by the Chicago, Milwaukee & St. Paul Ry. and the Illinois Central Ry. These four roads use the Searles spiral. The length is so determined by the first three railways that the rate of increase in superelevation will not exceed ½-in. in 30 ft., 1 in. in 40 ft., and 1 in. in 48 ft. respectively, the superelevation being obtained entirely between the P.S. and P.C. On double track, the length of the transition at the leaving end of the curve is sometimes reduced about 20%. Transition curves are used on the New York underground railway and the Boston elevated railway.

The best transition curve is that on the principle of the cubic parabola, being

a short curve of varying radius, which is interpolated between the circular curve and its tangent. It must be such that, starting with an infinite radius (or D=0) at the P.C., it will have a degree at every point in direct proportion to the distance from the P.C., until, at the P.C.C., where it connects with and becomes tangent to the main curve, it is of the same degree as that curve. Such a curve approximates closely to that of the cubic parabola, and with it the curvature and superelevation commence at the same point. The curve commences easily, and its degree increases gradually and uniformly, and yet quickly, until at some point it attains the degree of the main curve, the maximum superelevation being attained at the same point. The main circular curve is then continued until, near its end, it is again run out by a transition curve of decreasing degree into the tangent. The centrifugal force will thus be created gradually, and be balanced at every point by a gradually increasing centripetal force from the superelevation, if the latter is precisely adapted to the speed; or, if not, the aggregate will be less and gradually created. The center plates of the trucks will move through the necessary angle quickly, and then remain unchanged until the curve is passed. The conclusions presented by Mr. Wellington in regard to this curve were as follows:

1.—The transition curve will deflect exteriorly from the given main curve. because the rate of curvature becomes continuously less.

2.—It will terminate in a tangent parallel to the given tangent, because the same central angle is consumed.

3.—The offset DP (=O), Fig. 208 (diagram 207), bisects the transition curve AC in M.

4.—The transition curve AC bisects the offset O in M.

5.—At any intermediate points, OO^1, at equal distances from the corresponding P.T.C.'s, or from the middle point M, the offsets to the transition curve from the tangent, or from the main curve produced, are equal.

6.—The average degree of curvature between the P.T.C. at A and any two intermediate points, O and O^1, varies directly as the distances to these points from the P.T.C.

7.—The square offsets, O or O^1, from the tangent or the main curve produced, vary as the cube of the distance from the P.T.C.

8.—Any offset, O, may be used with any curve to connect the main curve with the tangent, and the length of the curve only will vary, varying as the square root of half the length of the transition curve.

9.—The half length (n) of the curve (AM or MC) equals the central angle I divided by the degree of the main curve.

The curve may be laid out by deflection angles or by offsets, but as the differences of curvature are in most cases comparatively small, and the transit work, if rigorously done, becomes more complex, the offset method is particularly suitable. In all ordinary cases, for moderate length and offsets, the curve is sensibly a parabola, and bisects the total offset. The offsets to the curve from the tangent and the circular curve are equal at equal distances from the extremity of the curve, and the offsets at the quarter points are always 1/16 of the total offset, or almost imperceptible, so that for grading purposes the curve is rarely more than half as long in fact as it is in theory. The track centers as well as grading centers may be laid out by offsets alone in all ordinary cases, with practically perfect accuracy. The objection is sometimes made that the method of laying out the curves by offsets is but a rough approxi-

mation to the true curve. Such objections (like those to simple methods of laying out turnouts) are apt to be made on theoretical considerations and without due allowance for the fact that delicate and minute measurements are sometimes out of place and useless in track work.

Many miles of track centers have been set by this method, and the track is practically equal to that on which the centers have been set directly from the transit, while the cost is very much less. In general, when circumstances permit, the best way for determining a transition curve is to assume a length, and let the offset at the P.C. come where it will. In many cases this is impossible or inexpedient, and the practical case is that the offset F is given a fixed length, and a curve must be put in to fit it. The offsets should vary approximately as the cube of the degree of curvature of the main curve, and while differences in speed may properly be considered in selecting particular transition curves, that does not prevent the law from being as stated if it is desired to use curves changing in degree by a given quantity in a given distance. The minimum length of offset for a 2° curve, or any other transitioned curve, should be as large as can be conveniently obtained up to a foot or more, provided high speeds are expected. If they are not expected, or if there are many other much sharper curves, a 2° curve may, without sensible harm, be left without transition curves. In any case it is a waste of time to trouble with offsets less than 0.1 in. (or even so small), as within a year after the track is laid it will almost certainly, under the trackmen's attention, vary more than that; often four or five times as much. In the application to compound curves, the transition curve to connect two curves, D° and $D^{1\circ}$, is practically identical (as to lengths and offsets) with one connecting a tangent with a curve whose degree is equal to the difference between the degrees of the two curves.

For laying out transition curves on the track to fit existing circular curves, the following method has been developed by Mr. F. E. Smith. The arc BA

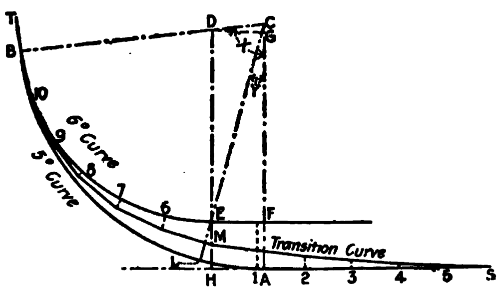


Fig. 209.—Laying Out Transition Curves.

in Fig. 209 represents a 5° circular curve with P.C. at A. The transition curve is to be 300 ft. long, which gives 12 chords of 25 ft., six being opposite the curve and six opposite the tangent. A 6° curve inside the main curve is assumed, as shown by the arc BE, the length being 150 ft., and center angle 9°, which gives an arc of 180 ft. The point of circular curve, B, is found by measuring 180 ft. from A on the 5° curve, and the tangent BT staked out. Six 25-ft. chords are then staked out on the 6° curve to the P.C. at E, with tangent EF parallel with the track tangent HA. The perpendicular HE is bisected at M, the point M being the middle of transition curve,

and HM the offset. The point H is fixed on the tangent of the 5° curve, and from it are measured six 25-ft. chords to S, which will be the P.C. of the transition curve. Divide the length of offset HM (in inches) by 216 and measure off as ordinates; once this amount at 5, 8 times the amount at 4, 27 times the amount at 3, 64 times the amount at 2, and 125 times the amount at 1. Starting again from E (on the 6° curve) measure off similar ordinates; that at 6 equal to that at 1; at 7 the same as 2, and so on to B, the P.C.C., where the transition curve merges into the circular curve. Stakes and tacks are driven at the ends of these ordinates and mark the line of the transition curve, which is shown by the line SMB. No formulas are required for the trackmen.

Another offset method, and which is specially adapted for application to existing track, is given by Mr. David Molitor, and has been used on the German government railways and the Illinois Central Ry. The circular curve is staked out on the ground in the usual manner, stakes being driven at the P.C., and on the tangent at distances $L \div 4$ and $L \div 2$, Fig. 208 (diagram 206), and also on the curve at the same distances from the P.C., the distance L being the length of transition curve as given in Table No. 32. Having these five stakes, offsets are measured towards the center of the curve as given in the table, and stakes set at the ends of these offsets are the track centers. The position of the circular curve between its two transition curves is given by the constant offset M. The figures given in Table No. 29 are sufficient for all practical purposes. In the equation for the curve, LR is a constant, 173,800, which is found to give good results without excessive values for M. The length of transition curve is then as in formula (8). For points between O and the P.C., the ordinate U from the tangent is given by formula (9), and for points between the P.C. and N, the offset S from the circular curve is given by formula (10).

$$(8)\ L = \frac{173{,}800}{P}. \qquad (9)\ U = \frac{X^3}{6LR} = \frac{X^3}{1{,}042{,}800}. \qquad (10)\ S = \frac{X^3}{6LR} - \frac{(X-L)^2}{2R}.$$

TABLE NO. 32.—OFFSETS FOR STAKING OUT TRANSITION CURVES FROM CIRCULAR CURVES.

Degrees of curve, Degs.	Mins.		Radius, R, ft.	L, ft.	Offsets: $X=\frac{L}{4}$ U, ft.	$X=\frac{L}{2}$ T, ft.	$X=\frac{3L}{4}$ S, ft.	$X=L$ M, ft.
2	00	....	2,864.9	60.7	0.003	0.027	0.051	0.054
2	15	....	2,546.6	68.3	0.004	0.038	0.071	0.076
2	30	....	2,292.0	75.9	0.006	0.052	0.098	0.105
2	45	....	2,083.7	83.4	0.008	0.069	0.130	0.139
3	00	....	1,910.1	91.0	0.011	0.090	0.176	0.181
3	15	....	1,763.2	98.6	0.014	0.115	0.216	0.230
3	30	....	1,637.3	106.2	0.018	0.143	0.269	0.287
3	45	....	1,528.2	113.7	0.022	0.176	0.330	0.352
4	00	....	1,432.7	121.3	0.027	0.214	0.401	0.428
4	15	....	1,348.5	128.8	0.032	0.257	0.481	0.513
4	30	....	1,273.6	136.4	0.038	0.304	0.570	0.608
4	45	....	1,206.6	144.0	0.045	0.358	0.671	0.716
5	00	....	1,146.3	151.7	0.052	0.418	0.783	0.836
5	15	....	1,091.7	159.3	0.060	0.484	0.907	0.968
5	30	....	1,042.1	166.8	0.069	0.556	1.042	1.112
5	45	....	996.9	174.4	0.079	0.636	1.191	1.271
6	00	....	955.4	181.9	0.090	0.722	1.352	1.443

Parabolic curves are used instead of circular curves to a limited extent, with the idea that they ride more easily. They are, however, of comparatively little effect as far as transitioning is concerned, and the same may be said of the plan of throwing in the whole of the curve except about 100 ft. at each end, connecting with the tangents. Mr. Wellington pointed out in the field

book which he left uncompleted at his death, that if we connect the same tangents and tangent points by parabolic instead of circular arcs, we shall obtain curves which are ordinarily of only slightly longer radius at the P.C. and P.T. than the circular arc. Thus the objectionable features of the curve connections are only slightly alleviated, and there is the disadvantage that the curve is correspondingly sharpened in the center. While the increase in radius is inconsiderable, a new and unfavorable effect is created; as the degree of a parabolic curve is constantly changing, and the change is very slow, the angle of the axis of the trucks to the axis of the car is likewise constantly changing, but with extreme slowness. Under these conditions the coefficient of friction between the center plates becomes a maximum, and the flange pressure and danger of the center plates binding and causing derailment are both materially increased. With the parabola, it is true, unlike the circle, it is unnecessary to have the tangents equal. If unequal tangents are used, we improve conditions at one end of the curve, but introduce less favorable conditions at the other end. On the whole, the parabola is not a desirable railway curve, as compared with the circle, even if it were more easy instead of more difficult to lay out.

Tangents and Ordinary Curves.

The longest tangent in the world is one of 205 miles on the Buenos Aires & Pacific Ry., in South America. The Canadian Pacific Ry. has a 90-mile tangent from Regina. Among the easiest curves are two on the Central Ry. of Georgia: 150,000 ft. radius (2¼ mins.), 26,500 ft. long; and 20,000 ft. radius, 8,374 ft. long. The Montana Central line of the Great Northern Ry. has a 30-min. curve about a mile in length. Curves of 6° should as far as possible be the maximum for important main lines with high speed; curves of 8° to 10° are used, mainly on mountain divisions and on branch lines. The Illinois Central Ry. has adopted 4° as its maximum. On the South & Western Ry., built across mountainous country to carry a heavy freight traffic, the limit is 8°. The objections to curves have already been noted. Many railways have spent large sums of money in taking out or flattening curves to improve the alinement and reduce the total curvature, especially where there is heavy and fast traffic.

Sharp Curves.

Sharp curves exist on many main lines, being introduced necessarily sometimes on difficult location in order to keep down the grades, to avoid heavy works, or to reduce the cost of construction. The Canadian Pacific Ry. for many years had at a point along the Kicking Horse River a curve of 22°, about 755 ft. long. It was at first laid with a superelevation of 6 or 7 ins., but as much grinding took place the rails were placed level and the gage was widened to 4 ft. 10 ins. Guard rails were placed at both track rails to guide the wheels and carry the blind tires of locomotives. Engines with a rigid wheelbase of 14½ ft. passed this curve, and the maximum speed was 10 to 15 miles per hour. This curve has now been abandoned, a cut-off with tunnel and 8° curve having been built. In reducing the grades between Field and Hector, B. C., this road has introduced two spiral tunnels, on curves of 10° covering central angles of 234° and 232°, one of which ends in a 10° reverse curve. The New York Central Ry. and Pennsylvania Ry. own jointly a line in the mountain-

ous country of western Pennsylvania, and the Fleming summit on this line (near Cherry Tree, Pa.) has a loop at the end of practically parallel tracks; it is a 10° curve covering 248½° of central angle, connected at one end to 10° reverse curves and at the other end to a long 2° curve. The Lake Erie & Western Ry. had at the passenger station at Lafayette, Ind., a long compound curve with a maximum of 30°, and a total angle of 69½°. The gage was widened ¾-in. and the outer rail elevated 2½ ins. The guard rail space was 4 ins., and planks were spiked outside the inner rail to carry blind driving-wheel tires. By rearranging the tracks, this has been reduced to a curve of 10¾°, with the same total angle; the superelevation is 2 ins., and the gage is not widened.

The Erie Ry. has on its Jessup branch an 18° main-line curve on a grade of 2.3%. The gage is 4 ft. 9 ins., and the superelevation is 5¼ ins. The maximum main-line curve on the Illinois Central Ry. is 24½°, but for new work the maximum is 4°. The New York Central Ry. and the Pennsylvania Ry. have adopted loop curves at the ends of the electrically operated sections at New York. The former proposes to use a curve of 140 ft. radius, with slight superelevation as the speeds will be low. This will be only for the suburban trains on the multiple-unit system, the cars for which have platforms and draft gear specially constructed to permit of their passing a curve of this radius. The Pennsylvania Ry. will use a curve of 600 ft. radius, but this will be for the use of the electric locomotives. The Boston Elevated Ry. has a maximum curve of 82 ft. radius, and others of 100 ft., 200 ft. and 300 ft.

Very sharp curves are occasionally required in yards, at Y's, and particularly for spur tracks entering warehouses, grain elevators and industries. Curves of ordinary yard tracks may be of 10° to 20°, and 30° for industry spurs. A single car can be hauled round a curve of 40 ft. radius, as in entering a warehouse, etc., where room is limited and land is valuable. Where two or more coupled cars are run, the radius may be 90 or 100 ft., though there may be occasional trouble from the corners of the cars striking each other, unless long coupling links or bars are used. It is not generally advisable to use four-wheel switch engines on curves of less than 75 ft. radius. The outer rails may be wide and flat to give a bearing to the wheel flanges of cars. On all such specially sharp curves care should be taken to have the curvature uniform and regular, the gage properly widened, rails braced, guard rails properly set, and the maintenance properly attended to. A curve of 79½ ft. radius at the Atlantic Terminal, Brooklyn, has a gage of 4 ft. 9¼ ins., and a superelevation of 4 ins. The quarry line of the Limerock Ry., at Rockland, Me., has a compound curve of 80, 68 and 75 ft. radii, with a contained angle of 110°; it is operated by a six-wheel switching engine. A small yard of the Central Ry. of New Jersey on the Harlem River, New York, has tracks of 90 ft. and 104 ft. radius, surrounding an oval freight house. The gage is widened 1 in., but there is no superelevation. Ordinary cars coupled together can be handled if the distance between center pins and couplers is about the same in each of the cars. Cars having a body length of 40 ft. or more must be handled singly and with care, being coupled to the switch engine by a rod. A four-wheel side-tank switching engine is used, having 7 ft. wheelbase. The wheels are 4 ft. 5⅜ ins. back to back, and have tires 6 ins. wide, with 1¼-in. flanges. Curves of the same radii in a similar yard of the Lehigh Valley Ry. had the gage widened ½-in., and the outer rails elevated 2 ins. The Lake Shore & Michigan Southern Ry. has at the Ashtabula yards a 16° curve used by 50-ton loaded ore

cars and 65-ton six-wheel switching engines with 11 ft. 3 ins. wheelbase. As the car enters the curve, the body tilts, and the heavy load thus thrown on the side bearings prevents the trucks from taking a radial position. The wheel flanges are thus held against the outer rail. The engines also wear the rail very rapidly, and cut off the inside lip caused by the flow of metal under the heavy pressure. The ten-coupled (0–10–0) switch engines of this road traverse curves of 22° at Ashtabula, and 12° at Elkhart and Collinwood; the engines have a wheelbase of 19 ft. The Erie Ry. has at Paterson, N. J., an industry track with a curve of 53½°; the gage is widened from ½-in. to 1-in., and there is a guard rail the full length of the curve.

The Cleveland, Cincinnati, Chicago & St. Louis Ry. had at the Cincinnati terminals two curves of 70 ft. radius, around which freight cars passed easily, as well as a switching engine with a wheelbase of 7½ ft. The shackle bar between the engine and tender was slightly lengthened, and the feed hose transferred from the sides to the center line to prevent the corners from jamming and tearing the hose. Bar links with holes 12 ins. apart were used between the cars to keep the corners from striking. Two to four cars were usually handled. The gage was spread 1½ ins. At the same city the Pennsylvania Lines had two sidings of 50 ft. radius into a beef storehouse, each turning an angle of 90°. A four-wheel engine with 7 ft. wheelbase was used, but as the street rails got filled with dirt it was the practice to rope the cars in and out. Engines with six driving wheels work regularly over sidetrack curves of 80 and 100 ft. radius. In the old arrangement the yard at the Grand Central Station, New York, there were spurs of 75 and 80 ft. radius to the express warehouse. These were satisfactory for baggage cars, 50 ft. long. A four-wheel switch engine, with four-wheel tender, was used, adapted to these curves by lengthening the drawbar so as to separate the end frames by a distance of 16 ins. The tires were 5½ ins. wide, with 4-in. treads and 1-in. flanges. The wheel gage was 4 ft. 5½ ins. back to back of tires, and the track gage 4 ft. 9 ins. The driving wheelbase was 8 ft.

Guard Rails on Curves.

A guard rail or check rail inside the inner rail may be used on sharp curves to hold the wheel flanges away from the outer rail. Such rails are sometimes used on main track (as on high banks or on mountain divisions), but more generally in yards. It is probable that they are particularly needed on the main tracks of electric railways operated at high speed, especially when electric locomotives are used, having the motors on the driving axles. On very sharp curves, a guard rail is sometimes laid on the inside of the outer rail (leaving 1¾ ins. flangeway), and another rail (or a heavy plank) outside of the inner rail, and as close to it as possible. These are to help support the blind or flangeless tires of driving wheels when they have a dangerously narrow bearing on the track rails on these curves. The practice in regard to curve guard rails is very diverse. They are used on curves sharper than 10° or 12° on some roads, and 20° to 25° on others. The width of flangeway ranges from 1¾ ins. (plus the amount of widening of gage on the curve) to 2½ and 3 ins., and even 5 ins. In some cases it is considered that the rails should be used on all curves sharper than 12° or 15° to prevent derailment, being so placed as to come into action only as the flange begins to tend to mount the outer rail. This requires a spacing of 3½ ins. to 4 ins. For guard rails at frogs and

crossings. the flangeway is usually 1¾ ins., but this would be bad practice on ordinary curves, as it would relieve the flange from action and throw all the normal guiding upon the guard rail. It is only admissible to throw guard rails into constant action on extremely sharp curves, such as those of elevated railways, where the guard rails are kept well lubricated. On the New York elevated lines the flangeway for curve guard rails is 2¼ ins., while in the subway or underground lines it varies from 2 to 2¼ ins. The widths on the Chicago South Side Elevated Ry. and the Boston Elevated Ry. are given in Table No. 33.

TABLE NO. 33.—FLANGEWAY AND GAGE ON SHARP CURVES.

Flangeway.	Curve Radius: Chicago.	Curve Radius: Boston.	Gage Widened, Boston.
.. ..	....	90 ft.	⅝-in. to ¾-in.
2¼-ins.	96 to 123 ft.	90 to 125 ft.	½-in.
2⅛-ins.	124 to 172 ft.	125 to 150 ft.	⅜-in.
2 ins.	173 to 287 ft.	150 to 230 ft.	¼-in.
1⅞-ins.	288 to 864 ft.	230 to 500 ft.	⅛-in.
1¾-ins.	865 and over.	500 to 5,000 ft.	0

Widening Gage on Curves.

It is a general practice to widen the gage on curves in order to allow locomotives to pass without undue friction (and wear) of rails and wheel flanges, or a dangerous liability of the wheel flanges to climb the rail. There is great diversity in the rules governing this widening. It may be said, however, that it should be used as little as possible, that the amount of widening should be as small as possible, and that special care should be taken to insure that the section foremen do not introduce excessive widening beyond that allowed. One reason for the lack of uniformity in practice is in the character of the locomotives employed. The principal factors are as follows: (1) The length of rigid and flanged wheelbase of engines; (2) The clearance between rails and wheel flanges; (3) The lateral play of the wheels (usually about ⅛-in.); (4) The distance from truck center to front driving axle; (5) The side motion or lateral play of the truck. The driving wheelbase of engines with four pairs of driving wheels is usually about 16 to 18 ft., and in order to facilitate the passage of curves it has been customary to use blind or flangeless tires (of extra width) on one or more pairs of wheels. The present tendency, however, is to use flanged tires on all the wheels, which may impose severe conditions upon the track at sharp curves and thus cause trouble and expense in maintenance-of-way.

To offset this to some extent, a little extra clearance is often given to the front and rear wheels. The standard width back to back of wheels is 53⅜ ins. Some eight-coupled (2–8–0) engines, with all wheels flanged and 16 ft. wheelbase, have 53¼ ins. for the first and fourth pairs, and 53½ ins. for the two middle pairs; other similar engines have 53 ins. and 53¼ ins. respectively. Ten-coupled switching engines (0–10–0), with all wheels flanged and 19 ft. wheelbase, have 53⅜ ins. for the second and fourth pairs, and 53⅛ ins. for the others. The wheel gage ordinarily gives ⅝-in. to ⅞-in. clearance on tangents, and there is no necessity for widening the gage of track as long as the clearance between the wheel flange and rail allows the engine to travel round the curve without binding or exerting undue pressure. The following formulas of the Roadmasters' Association (1898) are modified from others worked out by Mr. W. H. Searles: D = degree of curve beyond which widening will be necessary; A = distance from driving axle to truck pin; B = driving wheelbase; S = side play of truck; P = play allowed by wheel flanges.

$$D = \frac{956}{A \times B}\left((P - \tfrac{1}{4}) + \frac{\tfrac{1}{2}BS}{A+B}\right). \qquad P = \left(\frac{DAB}{956} - \frac{\tfrac{1}{2}BS}{A+B}\right) + \tfrac{1}{4}.$$

On some roads the widening begins with ⅛-in. for 1°, and increases about 1/16-in. per degree of curve (or ⅛-in. for each 2°). On others it begins with ⅛-in. at 4° to 6°, the minimum on the Chicago, Milwaukee & St. Paul Ry. being 6°. In still other cases a uniform widening of ½-in. is required for all curves over 8° or over 12°. On the New York Central Ry., the widening varies by ¼-in., and is ¼-in. for curves of 6° to 10°, ½-in. for 10° to 14°, ¾-in. for 14° to 18°, and 1 in. for 18° and over. On the Atchison, Topeka & Santa Fé Ry., it is ⅛-in. for curves of 1° to 2° (inclusive), ¼-in. for 3° to 5°, ⅜-in. for 6° to 8°, and ½-in. for 9° to 11°. The South & Western Ry. uses ¼-in. for curves of 9° to 12° (inclusive), and ½-in. for curves over 12°. The Illinois Central Ry. uses ⅛-in. for curves of 3° up to 5°, 3/16-in. for 5° and up to 7°, ½-in. for 7° and over.

The practice on some other roads is shown in Table No. 34. The Southern Pacific Ry. allows ¼-in. excess for rail wear, but the gage must never exceed 4 ft. 9¼ ins. The maximum permissible widening is usually 1 in. The widening of very sharp curves on elevated railways is given in Table No. 33. The gage at frogs and switches should be the same as on the adjoining track, but some roads widen the gage on the turnout track in all cases. The Atchison, Topeka & Santa Fé Ry., for instance, makes the gage 4 ft. 9 ins. at all turnouts, whether on curves or tangents. The widening extends through the switch and frog and narrows to 4 ft. 8½ ins. in a distance of 30 ft. beyond the frog. The gage of 4 ft. 9 ins. is also used for yard tracks from which many leads turn out. The widening should be effected by shifting the inner rail outward, keeping the outer rail at a uniform distance from the track centers throughout, and using this as the line rail. Great care should be taken to see that an excessive gage does not result from widening combined with wear and lateral movement of rails. Special track gages may be furnished to foremen having curves of over 5°; that of the Louisville & Nashville Ry. has two fillers to set against the lugs and give a widening of ¼-in. and ½-in.

TABLE NO. 34.—WIDENING GAGE ON CURVES.

Curve. degs.	L. & N. in.	Nor. Pac. in.	C. & N. W. in.	Ph. & Read. in.	Sou. Pac. in.	Curve. degs.	L. & N. in.	Nor. Pac. in.	C. & N. W. in.	Ph. & Read. in.	Sou. Pac. in.
1	..	⅛	..	..	..	8	⅜	⅜	5/16	¼	½
2	..	⅛	..	..	..	9	⅜	⅜	⅜	¼	..
3	..	⅛	⅛	..	..	10	½	½	7/16	⅜	..
4	⅛	¼	⅛	..	..	11	½	½	½	⅜	..
5	⅛	¼	3/16	⅛	⅛	12	⅝	½	9/16	½	..
6	¼	¼	3/16	⅛	¼	13	⅝	⅝	⅝	½	..
7	¼	⅜	¼	⅛	⅜	Over 13	⅝	⅝	..	⅝	..

Superelevation on Curves.

On tangents, it is important that the heads of both rails should be kept at the same level. or in the same horizontal plane, so as to insure easy and steady riding of the cars. On a curve, however, the centrifugal force causes the train to tend to travel in a straight line, thus throwing a severe and dangerous pressure of the wheel flanges against the outer rails. To reduce this, the outer rail is elevated above the inner one, to such an extent that the rails will be in an inclined plane at right angles to the resultant of the gravity force and centrifugal force acting upon the train. With a train traveling upon such an inclined plane, a centripetal force is developed which tends to cause the train to run in a curve instead of in a straight line. Where there is the exact relation of the inclination (or superelevation) to the resultant, the centrifugal

force acting in the plane of the track is eliminated as a factor in the lateral pressure against the outside rail, and the factors then to be dealt with are the pressures and frictional resistances due to deflecting the wheels from the straight line (in which they tend to move) and compelling them to follow the curve. The amount of this superelevation depends upon the degree of the curve and the speed of the trains, but in practice the important factor of speed is a variable in each case. Fast and slow trains travel over the same tracks, so that it is impossible to exactly adjust the actual elevation to theoretical conditions. Thus a mean, or compromise, elevation must be adopted, taking into consideration the proportion of fast and slow trains. The centrifugal force of a moving train is calculated by the following formula. The super-

$$\text{Cent. force} = \frac{\text{Weight of train (tons)} \times \text{Square of velocity (feet per second)}}{32\ 2 \times \text{Radius of curve (feet)}}$$

elevation (E) required to counteract this lateral force is sometimes taken as 1/10 of the square root of the degree of the curve, giving the elevation in decimals of a foot. It is usually calculated, however, by any of the formulas given below, the result in each case being in inches. Where the "gage'' is a factor, this should properly be taken as the distance c. to c. of rails (4.9 ft.) and not the gage distance between rail heads (4.7 ft.). The gage board (see "Tools'') being set level on the rails, and the rail heads being tilted by lying in an inclined plane, the board rests practically on the outer and inner corners of the outer and inner rails respectively. Corrections for width of rail heads, however, are an undue refinement, the actual elevation being a compromise, as noted above.

$$E = \frac{\text{Gage, or distance c. to c. of rails (inches)} \times \text{Sq. of velocity (ft. per second)}}{32.2 \times \text{Radius of curve (feet)}}.$$

$$E = \frac{\text{Square of velocity (miles per hour)} \times \text{Distance c. to c. of rails (feet)}}{1.25 \times \text{Radius of curve (feet)}}.$$

$$E = \frac{\text{Chord}^2}{\text{Radius} \times 8}. \quad E = 0.06688 \frac{\text{Gage (or 0.9 ft.)} \times \text{Velocity squared (miles per hour)}}{\text{Radius (feet)}}.$$

The conditions in regard to grades, train service, etc., have an important relation to the acquired amount of superelevation. Good judgment must be exercised in giving the elevation according to the location and degree of the curve, the range of speeds, and other local conditions affecting the traffic. In fact the proper elevation for each curve must be the subject of investigation. A 6° curve at the top of a grade should have less elevation than a 6° curve on level track or at the foot of a grade. On double track, the track on which trains ascend should have less elevation than that on which they descend, as ordinarily the former trains will have a lower speed. If the rules require reduced speed on certain curves, these curves will require a proportionately less elevation than curves on which trains are run at normal speed. On sharp curves near stations or crossings, etc., where trains always stop, but little elevation is required, as the speed is slow. The same applies to similar curves near the summit of grades. It is not uncommon, however, to find excessive elevation at such locations, calculated for much higher speeds than can be obtained in service. On single track, a curve in a sag of grades may have the elevation increased to provide for the speed of trains making a run at the grade. On double track, a derailment on the inner side of the outer track would foul the inner track, and this also must be taken into account.

The maximum elevation is usually limited in practice to 6 ins. (or 8 ins. at most). Greater amounts may be called for theoretically, but as a rule the fastest trains represent a comparatively small proportion of the traffic. With modern rolling stock, having heavy wheel loads and a high center of gravity for locomotives and cars, an elevation of 8 ins. on a curve throws a very heavy load on the lower rail. This may be dangerous, especially as the springs yield on the lower side while those on the higher side react, thus tending to give the car floor an inclination greater than that of the track. If the elevation is too high for slow speeds the weight on the outer rail is reduced, which makes it easier for the wheel flange to mount the rail. This also introduces the liability of getting heavy slow trains stalled on the curve, owing to the severe flange pressure and weight on the inner rail, especially if the grade is not compensated for curvature. Heavy slow trains on curves elevated for high speed may cause distortion or flow of metal in the rail head.

If a railway has many very sharp curves and operates a high-speed traffic, it may be desirable to change the alinement for reasons of safety in operation as well as economy in maintenance. On most railways, there is a standard table of superelevations for different curves and speeds, and such elevation is used as is required by the special conditions at individual curves. The actual elevation for any curve is selected (as already noted) to suit practical considerations of traffic and location, maximum safe elevation, and reduction of speed due to curve resistance. The tables serve only as guides, and must not be followed blindly. The elevation is usually calculated for passenger-train speeds, so as to insure easy riding, unless that elevation will be such as to interfere with slow freight trains. In determining the elevation for a mixed traffic with various speeds, it is usually best to give greater consideration to the fast than to the slow trains, unless the latter are very numerous and very heavy. In some cases, varying rates are specified to suit different operating conditions.

It is, of course, useless to carry out the tables to very high figures, because (for reasons already given) the elevation cannot be carried beyond certain limits; while on very sharp curves fast trains are usually required to reduce speed for considerations of safety, so that a less elevation may then be introduced. The actual elevation is a compromise, and the maximum is usually confined to tracks used extensively by passenger trains at high speed, as it is too high for heavy freight trains moving at a moderate speed. Whatever amount of elevation is decided upon, this amount should be maintained uniformly around the curve, as irregularity in this respect seriously affects the riding of the cars, and may introduce an element of danger. For this reason, among others, foremen should frequently test the elevations of their curves. The degree of curve and the proper elevation may be marked on a stake driven at each end of the curve (or at the beginning of the curve on double track). Stakes may be set to the required elevation; that is, 0 at the beginning, and the maximum elevation at the point where this maximum is reached.

The practice as to superelevation on different railways varies very considerably. In some instances it begins with $\frac{7}{8}$-in. for 15 miles per hour on a 1° curve, and runs to a maximum of 7 ins. on 8° curves. In other cases it begins with $\frac{1}{8}$-in. for 15 miles per hour on a 1° curve, and runs to a maximum of 3 ins. at that speed, for a 20° curve. The Southern Pacific Ry. gives the trackmen two elevation tables; one of these is for main lines (except mountain

divisions with grades of over 1.8%), and is calculated for a speed of 36 miles per hour; the other is for mountain divisions with grades of over 1.8%, and for branch lines, and is calculated for 25 miles per hour. The Baltimore & Ohio Ry. gives two rules: one for single track, with trains in both directions; the other for double track on descending and light ascending grades. The South & Western Ry. uses ¾-in. per degree, the maximum being 5¼ ins. for a maximum 8° curve. The Chicago, Milwaukee & St. Paul Ry. elevates the curves on its high-speed lines for 60 miles per hour, with a maximum of 6 ins. The St. Louis & San Francisco Ry. uses 1-in. per degree for main lines, with a maximum of 6 ins. On branch lines, and at the top of long grades where speed is actually reduced, it uses ¾-in. per degree, with a maximum of 5 ins. For a curve at the bottom of a grade where trains run at high speed, the elevation is increased 1-in., with a maximum of 7 ins. The New York Central Ry gives the following elevations, the maximum being 6½ ins.; main passenger tracks, curves under 2°, twice the middle ordinate of a 62-ft. string; 2° and over, middle ordinate + 2 ins.; main freight tracks, ¾ of middle ordinate; combination tracks, middle ordinate; sidetracks, such elevation as may be deemed necessary by the resident engineer or roadmaster to meet local conditions and speeds.

Where the degree of curve is not known, the elevation may be ascertained by taking a string of given length, holding the ends to the gage line of the rail, and measuring the ordinate from the center knot to the rail, which will be the required amount. In using the string, measurements should be taken at different points, so that any specially sharp or flat places in the curve (which should be corrected when discovered) do not mislead in setting the elevation. The length of string may be obtained by multiplying the speed in miles per hour by 1.587. The Southern Pacific Ry. specifies the middle ordinate of a string 64 ft. long on main track (based on 36 miles per hour), and 44 ft. long on branch lines (based on 25 miles per hour). The Philadelphia & Reading Ry. requires the elevation to be equal to the middle ordinate of a chord (or string) whose length is that of the number of feet per second traversed by the average fast train. The practice on different railways is shown in Table No. 35. On the Boston Elevated Ry., with curves as sharp as 82 ft. to 200 ft. radius, the maximum elevation is 4 ins., which is run out on the transition curves. On the South Side Elevated Ry., Chicago, the elevation is 4½ ins. for curves up to 300 ft. radius, 3 ins. up to 500 ft., 1⅞ ins. up to 700 ft., and ⅞-in. for curves of over 700 ft. radius.

The superelevation must, of course, be attained gradually. With circular curves this run-out is formed usually on the tangent, giving the full elevation at the P.C. and around the entire length of the curve. In some cases it is distributed over the tangent and the beginning of the curve, and the Chicago, Milwaukee & St. Paul Ry. puts only 66% of the run-off on the tangent, and only 66% of the elevation at the P.C. The method first described is the best and most generally used. By slightly raising the rail on the tangent, the wheels tend to run towards the high rail, and are thus put in the best position for taking the curve. The rate of the run-out is very generally 30 ft. (or 33 ft.) for each ½-in. of elevation, but this is not enough for high-speed trains, in which the rise may sometimes be distinctly felt. The New York Central Ry. makes it 30 ft. for each ½-in. up to 3 ins. elevation; for greater elevation, the length must not exceed 360 ft. The Louisville & Nashville Ry. uses 40

ft., and the Illinois Central Ry. 50 ft. per inch of elevation, where no transition curves are used. The Atchison, Topeka & Santa Fé Ry. uses a uniform length of 120 ft., the maximum elevation being 5¼ ins. On double track, the Chicago & Northwestern Ry. makes the run-out at the leaving end about twice as long as that at the entering end of the curve. The New York Elevated Ry. uses a length of 30 ft. for 90-ft. curves, and 50 ft. for 350-ft. curves. The South Side Elevated Ry., Chicago, gives a run-off of $\frac{1}{32}$-in. per tie between ties spaced 18 ins. c. to c.

TABLE NO. 35.—SUPERELEVATION OF CURVES

Curve.	So. Pac.*		Ill. Central				N Y Central					Louis & Nash. †					
	Speed in miles per hour																
degs.	A	B	30	40	50	60	20	30	40	50	60	15	30	40	50	60	Speed Limit
	Elevation in inches																
1...	1	¾	½	1	1½	2	¼	½	1	1¾	2½	¼	¾	1¼	1¾	2¼	60
2...	2	1½	1	2	2⅞	3¼	½	1¼	2¼	3½	5	½	1⅛	1⅞	3	4⅛	60
3...	3	2¼	1½	2⅞	4⅛	5¼	¾	1¾	3¼	5	7¼	⅝	1¾	2⅞	4¼	5¾	60
4...	4	3	2	3¾	5¼	6½	1	2½	4½	6¼	..	¾	2¼	3⅞	5¼	6¾	60
5...	5	3¾	2½	4½	6¼	..	1¼	3	5½	.	..	⅞	2¾	4½	6⅛	..	55
6...	6	4½	3	5¼	..	..	1¾	3¾	6½	.	..	1⅛	3¼	5⅛	7	.	50
7...	..	5	3½	6	..	..	2	4¼	7½	..	..	1⅜	3⅞	6	..	..	45
8...	..	..	4	..	..	..	2¼	5	..	..	.	1⅝	4¾	..	.	..	35
9...	..	..	4½	..	..	..	2½	5¼	..	..	..	..	..	..	..	..	..
10...	..	..	5	..	..	..	2¼	6¼	..	..	..	2	5½	..	..	..	30
11...	..	..	5½	..	..	..	3	6¾	..	..	..	..	..	..	..	..	..
12...	..	..	6	..	..	..	3¼	7¼	..	..	..	3	..	..	..	..	25
13...	..	..	..	..	..	..	3½	8	..	..	..	..	.	..	..	..	..
14...	..	..	..	..	..	..	3¼	..	..	..	..	3½	..	..	..	..	14
16...	..	..	..	..	..	..	4½	.	..	..	..	4	..	..	..	..	16
20...	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	15

* Southern Pacific Ry.: (A) For main lines, excepting mountain divisions having grades over 1.8%; (B) For mountain divisions having grades over 1.8%, also for branch lines maximum elevation, 6 ins. Elevations are given for curves of half degrees, beginning at ½-in. for ½° curve for speed A, but for speed B the lowest is ¾-in. for 1° curve.

† Louisville & Nashville Ry.: This company gives a table for 11 rates of speed 10 to 60 miles per hour, with 3⅜ ins. for the lowest speed on a 30° curve. The maximum elevation is 7 ins. for curves up to 7°, 6 ins. up to 10°, and 5 ins. beyond 10°.

Where the curves are transitioned, the run-out usually coincides with the transition curve, so that the elevation conforms to the radius at every point. While this is theoretically correct, the St. Louis & San Francisco Ry. finds that it does not make an easy riding track. The elevation is therefore commenced on the tangent, two rail-lengths in advance of the spiral, and attains 1 in. at the beginning of this curve; it then increases 1 in. in 30 ft. to the full elevation at end of spiral. For such curves, a diagram of the elevation should be given to the foreman. On compound curves, the sharper curve should have the full elevation on its entire length, running out on the flatter curve to the elevation of the latter, which has its run-out on the tangent. On reverse curves, or curves with very short tangents between them, the elevation must be made gradually on the curves, commencing at the point of reverse or at the middle of the short tangent. The high rail should be the line rail, and this rail is usually raised to the required elevation, the inner rail being kept at the grade level, with the minimum depth of ballast beneath it. On some roads the inner and outer rails are respectively lowered and raised by half the amount of superelevation, for the purpose of maintaining the center of gravity of the train uniform on curve and tangent. This has little effect in practice, and is objectionable in complicating the roadway section.

Curves on Bridge and Trestle Floors.

Where curves occur on bridges and trestles, special methods are required for putting in the elevation. For bridges, the most general methods are (1)

to use tapered ties, (2) to put shims or blocks under the outer rail, (3) to put blocks under the outer ends of the ties. An objection to the second plan is that with any considerable elevation the rails get badly worn, as the inner rail is vertical (and sometimes both rails) and their heads are not in the same plane. Bridges may be inclined by putting the elevation in the rail seats of the masonry or in the shoes of the end bearings, but with any considerable elevation it is inadvisable to thus incline the girders or trusses. With trains at speeds lower than that for which the elevation is calculated, the load would not pass through the axis of the bridge and might subject the structure to strains not provided for in the design. In rare cases, the outer girder is made deeper, but this is not advisable, apart from the extra trouble in the design and manufacture of each structure. With through truss and girder bridges, however, the outer floor stringer may be raised. With ballasted floors, the ties are inclined in the ballast in the usual way.

The practice of some railways for plate-girder deck structures is noted below. Baltimore & Ohio Ry. Tapered ties are used up to a maximum thickness of 16 ins. at the butt, with the standard thickness under the inner rail. Beyond this, a cushion block is put on the outer girder, and the bottom of the tie is cut horizontal over the inner girder; the thickness under the inner rail must not be less than that of the standard tie. The block is the full width of tie, 2 ins. thick at the small end and about 4 ft. long; the inner side is spiked to the tie, and the outer end has a ¾-in. bolt through the tie, while the guard-rail bolts also pass through the tie and block.—Louisville & Nashville Ry. The deck girders have no top cover plates, and the web plate extends ¾-in. above

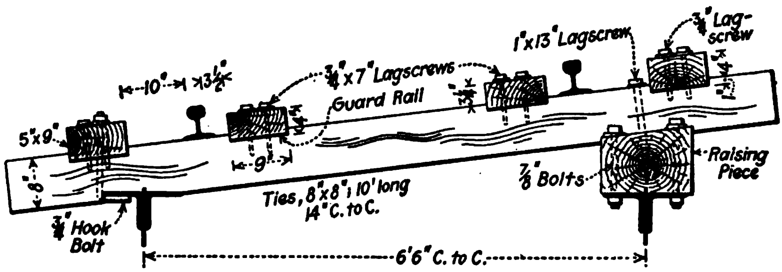


Fig. 210.—Superelevation of Curves on Bridges; Louisville & Nashville Ry.

the chord angles. With girders 6½ ft. apart, tapered ties 10 ft. long are used, 8 ins. thick under the inner rail and with a maximum of 14 ins. at the outer rail, beyond which the top is level. Where the elevation exceeds 14 ins., a timber of the proper depth and the full width over chord angles is laid on the outer girder, and bolted to it at intervals. Every other tie is secured to this timber by a lag screw 1×13 ins. at right angles to the face of the tie. Where the girders are 9 ft. apart, the tapered ties are 11 ins. thick under the inner rail, and not more than 16 ins. under the outer rail. Over the inside girders the ties are in all cases boxed to give a level bearing on the chord, as shown in Fig. 210.—Pennsylvania Lines. For girders spaced 6½ ft. apart, and with ties 9 ft. long, tapered ties are used for elevations up to 6 ins., the minimum thickness of the tie being 6½ ins. where it is boxed out for the girder. The bolt of the outside guard timber passes through the block and tie, and has a clip washer fitted to the edge of the chord angle. Where the rails rest on wooden floor

beams (as in through plate-girder bridges), elevation blocks are placed between the floor beam and the outer rail.—Philadelphia & Reading Ry. Beveled blocks are placed on the tie, under the outer rail.

Elevated Railways.—The South Side Elevated Ry., Chicago, uses tapered ties except where conditions require the standard 6-in. ties. In the latter case tapered shims are put on the ties, under the outer rail. These shims are 44 ins. long, and secured to the tie by 40-penny spikes. ("Engineering News," Aug. 18, 1904.) On the Boston Elevated Ry., tapered ties are used, with the standard thickness under the inner rail.

Trestles.—On timber trestles the elevation may be given under or above the caps. If corbels are used, those on the outer side may be made of the necessary extra thickness. Otherwise, elevating blocks may be placed between the caps and the outer stringers, or between the ties and the outer rail. Tapered ties are not often used. Cushion ties are thin tapered ties (about 3 ins. thick at the inner end), the full width and length of the ordinary ties upon which they are placed. Cushioned caps are similarly placed on the caps, and may be boxed out for the stringers. The boxing tends to hold water and cause decay, and in both cases water may cause decay between the contact surfaces of the two pieces. Neither of these methods is used to any extent. Occasionally the entire trestle is built on an incline to give the proper elevation. With a pile trestle the piles may be cut off at heights to give the proper elevation to the cap. With framed trestles, the mudsills may be inclined, so that the framing of the bents will not be affected, or the outer posts may be of increased length, keeping the mudsills level. The main objection is that, with slow trains, the weight on the inner rail would tend to throw most of the weight on the inner posts, so that only the sway bracing would resist the racking of the bent; with considerable elevation and a high trestle, this would be very great. This might be prevented by increasing the batter of the inner posts, but such special construction of bents is undesirable. A solid floor without ballast may have the floor system built to give the elevation, but if it is ballasted the ties will be inclined in the ballast as on the ordinary roadbed.

Lateral Pressures on Curves.

While the theoretical pressure of the wheel flange against the rail on a curve may be computed, the exact pressure exerted and its effects are practically indeterminate, owing to variations in conditions of speed, rolling stock and track. The various forces entering into the discussion of curve mechanics are not static but are dynamic, and there is a large amount of shock, impact and oscillation in the movement of a train around a curve. Then again, the parts which receive the stresses are elastic and yielding, and not rigid. Under these conditions the determination of force and stress can result only in an approximation. In resisting lateral pressure, the rail is held in position mainly by the weight of the train, and the coefficient of friction between the rail and the tie (or tie-plate) is a most important factor, which again varies indefinitely. If the tie-plates have lugs or shoulders to provide a bearing for the outer edge of the rail base, and are also mechanically locked to the body of the tie (or have bottom lugs to engage with holes in the face of a steel tie), the pressures on the rails are better transmitted to the tie and the track structure. The pressure is exerted by the wheel flanges at a point some distance above the

ties, and the resultant of this lateral force and the weight carried by the wheel may tend to tilt the rail or slide it outward upon the tie, according to the coefficient of friction between rail and tie. Any computations as to the pressures sustained by the spikes can be only approximate. There is little doubt, however, that in very many cases the factor of safety in the spiking is small, even when tie-plates are used. The conditions at any point may be aggravated materially: (A) By a badly curved rail; (B) By ice, frost or grease under the rail; (C) By a few outside spikes out of actual contact with the rail or driven in soft wood or old holes; or (D) by inside spikes pulled (by wave motion of the rail) so that their heads do not bear upon the rail base. The following points are to be borne in mind, and some of these have already been noted:

1. The centrifugal force of a train running around a curve tends to increase the weight on the outer rail and to reduce that on the inner rail, and at the same time to increase the pressure of the wheel flange against the outer rail. This may be counteracted by elevating the outer rail to develop a centripetal force. The centrifugal force is about 58 lbs. per ton on a 1° curve for a speed of 50 miles per hour, while the centripetal force is about 35 lbs. per ton per inch of elevation. (See "Superelevation.") 2. The superelevation is exact for only one of the numerous speeds at which trains pass over it. 3. The wheels tend to run in a straight line, and as the two wheels on each axle are rigidly fixed in their relation to each other, they must be slid laterally on the rail in passing the curve, and also moved or swung longitudinally for an amount equal to the difference in length of the inner and outer rails; (4) The guiding of the wheels of a truck around the curve is effected by the outer rail, against which the flange of the leading outer wheel presses, but a variable and important factor is the resistance offered to the movement of the truck by the friction on its center bearing, and sometimes also on the side bearings.

In the derailment of a train drawn by an electric locomotive on the New York Central Ry., on Feb. 16, 1907, one rail on a 3° curve was shifted bodily outward, sliding on the tie-plates and shearing off the spikes. The 95-ton locomotive was of the 2–8–2 class, with a motor on each driving axle, and a driving wheelbase of 13 ft. Comparisons were made between this engine and a 95-ton steam locomotive of the 4–4–2 class, and it was calculated that for the electric locomotive at 60 miles per hour the thrust of the leading truck wheel and first driving wheel would be 6,830 lbs., and 10,470 lbs. (with a spike shear of 2,780 lbs. and 5,820 lbs.); for the steam locomotive it would be 8,130 and 11,200 lbs. (4,890 and 3,0C0 lbs. spike shear). This was discussed in "Engineering News" of March 14, 1907. A very similar accident occurred Feb. 22, 1907, with a train drawn by a steam locomotive on the Pennsylvania Ry.; on the 3° curve the outer rail was slid out on the steel ties, shearing off the bolts. With the fastening used the rail clamps did not enter the bolt holes so as to assist the bolt, and the pressure was resisted only by the bolt bearing against the back of the hole, with, of course, a very limited bearing area. Tests as to lateral pressure were made on this road by M. G. L. Fowler, using a specially designed apparatus. An 87-ton consolidation engine was run at 30 miles per hour on a 4½° curve having a superelevation of 3¾ ins. for a speed of 36½ miles per hour. This showed a thrust of 13,430 lbs. for the truck wheel, and 11,450 lbs., 13,000 lbs., 12,215 lbs., and 11,170 lbs. for the driving wheels. Tests have also been made with cars, from which it appears

that the first wheel exerts the greatest pressure, the others in constantly reduced proportion. The front truck exerts about 60% of the pressure. The maximum lateral thrust of car wheels in ordinary service is estimated at 35,000 lbs. at 45 miles per hour, while the average strength of car-wheel flanges is about 80,440 lbs.

Switchbacks.

Switchbacks, instead of curves, are sometimes used where a railway is developed by a "zigzag" on a hillside in order to reach a desired elevation by practicable grades, and where there is no room to put in curves to connect the inclines. In this case the upper end of one incline and the lower end of the next unite in a Y, the stem of which is a stub or tail track. The ascending train pulls into this tail track; the switch is then turned, and the train backs out up the next incline. The tail track has an ascending grade to assist in stopping and starting the trains. On the Crown King extension of the Santa Fé, Prescott & Phœnix Ry. there is a switchback section 9 miles long, with 10 switchbacks, the train running backward on alternate inclines. The inclines are from 1,500 ft. to 4,000 ft. long, with maximum grades of 3½% (compensated) and 16° curves (with gage widened ¾-in.). The grades and curves are somewhat easier on the back-up sections. The tail tracks are 300 ft. long, with a 2% grade rising from the switchstand. The frogs are No. 6½ and No. 9. The trains weigh about 230 tons, including the locomotives, which are of the 2-8-0 class, with 13½ ft. wheelbase. The average speed over the switchback section is about 15 miles per hour. Very little time is lost in reversing; a brakeman drops off the train and turns the switch as soon as the rear end clears it, and the train is reversed at once. The system cannot be used for main lines with heavy traffic (see "Permanent Improvements"). The development of the Canadian Pacific Ry. in the Kicking Horse valley (in 1907-08), to increase the distance and reduce the grades from 4.5% to 2.2%, involved spiral tunnels in the mountains in order to obtain the 10° curves connecting the inclines. A similar arrangement at the Fleming Summit, in Pennsylvania (already noted), has the two practically parallel lines connected by a 10° curve.

CHAPTER 23.—TRACK INSPECTION AND THE PREMIUM SYSTEM.

The track is usually inspected daily by the trackwalkers, or by a man sent over the section on a velocipede. The section foremen and supervisors have also to make frequent examinations, not only in detail, but of the general condition of the track and roadway. The roadmasters and engineers should also make general inspections of the divisions under their charge. Special inspections must be made during or immediately after heavy storms, to insure that the railway is safe, and if there is any doubt, trains may be stopped or ordered to proceed slowly until the doubtful part has been inspected.

On many railways, especially where the premium system is in force, a general inspection is made once a year by the superior officers, record being kept of the condition of each section, station, etc., year by year. This inspection is usually made in the autumn, after the track has been put in condition for the winter. The officials mark on cards provided for the purpose, their rating

of the condition of each section. The markings of the cards are then figured up and prizes awarded according to the averages. In some cases the marking or judging is done by the roadmasters, engineers, division superintendents, etc.; but no man does any judging on his own division. Some roads make the foremen on each division the inspectors, each foreman marking on every section but his own. The annual inspection is thus made to educate and arouse the foremen. Each man becomes more critical of his own division, and in passing over the divisions he notes certain good and bad points, so that the system tends to make the general practice better and more uniform. It pays to take the foremen over the road together once a year, even if no prizes are given, as it gives them more interest in and knowledge of their work, while an incentive to good work, in the shape of a prize, is a good thing. It is well, also, to have a "Premium Section" sign board erected on the section tool house or elsewhere on the section, as the laborers feel that they are getting some recognition. The results of inspections should be announced by bulletins.

A private car with large end platform and windows may be used for inspections. Or a special car having the floor sloping up from the end and fitted with seats, while the end may be open or fitted with glass windows extending to the floor. The car is pushed ahead of an engine at the rate of 10 to 15 miles per hour. The Chicago, Burlington & Quincy Ry. has put an inspection cab on the front end of a locomotive, the floor being close to the ground. This seated 7 persons, while 5 more could be accommodated in an upper part extending back along the smokebox, and level with the running board. The throttle, whistle, brakes, etc., were controlled from the inspection cab. Light cars with gasoline engines may be used. A four-wheel car seating 8 to 10 persons on transverse seats, and having a roof, glass front, and side curtains for bad weather, may be equipped with an engine of 12 to 15 HP. and will weigh about 1,500 lbs. A lighter machine for four persons and with a 5-HP. engine may weigh 800 lbs. The fuel consumption for such cars would average 15 to 20 miles per gallon.

On the Pennsylvania Ry., the time for the annual inspection of the main line is selected by the general manager. It is usually about the middle of October, this time being fixed so as not to have the local officers away from their divisions at the end of the month. The inspection parties are of two classes: (1) The "limited," which comprises officials above the rank of supervisor; (2) The "general," in which all officials down to and including assistant supervisors participate. The inspection car resembles a large caboose, 36 ft. long. The front end is open, and the floor slopes up by steps to about the middle of the car, so that all the occupants may have a good view of the track. This part of the car is fitted with ordinary car seats, giving accommodations for 28 persons.

It is customary for the party comprising the "limited" inspection to leave Philadelphia on Monday morning, its special train arriving at Pittsburg in the evening. This party is made up of the general manager, chief engineer of maintenance-of-way, general superintendents, superintendents of the divisions over which the inspection is made, principal assistant engineers and assistant engineers of the main-line divisions between Jersey City and Pittsburg. The "general" inspection party is made up of all the participants in the inspection, who meet at Pittsburg prepared to move eastward on Tuesday morning. The movement of the inspection train is as follows: Tuesday over the Pitts-

burg and Middle divisions, Wednesday over the Philadelphia and New York divisions. The inspection party is carried usually in separate trains, the first train carrying the general manager and his party; the second train for the principal assistant engineer and assistant engineers of all the divisions; the third train for the supervisors; the fourth train for the assistant supervisors. These are followed by the track-indicator car in charge of the motive-power department. The use of this car is not considered as part of the inspection of the road, and has no connection with the annual inspection for prizes. The various branch-road inspections are arranged by the division superintendents and usually follow the main-line inspection. These are not held regularly.

The inspection is done by four committees: (1) Line and surface; (2) Joints and tie spacing; (3) Ballast, switches and sidings; (4) Ditches, road crossings, station grounds and policing. The marking is from 1 to 10, and zero is used where there are no sidings, road crossings, etc. In awarding prizes, a committee is appointed on each main-line division and so arranged that no officer of the division that is being inspected is a member of the committee on award for that division. The prizes awarded to supervisors after the annual main-line track inspection are as follows, all being for the entire line between Pittsburg and Jersey City: First prize, $1,200 for main-line supervisor (exclusive of yard supervisors) having best line and surface. Second prize, $1,000 for the supervisor having made the greatest improvement in his track during the year. Third prize, $800 for main-line supervisor having best line and surface on each superintendent's division. Fourth prize, $100 for main-line yard supervisor having best line and surface in the yard. The premium section is not marked by any sign.

The Wabash Ry. had a complete system of track inspection, and gave enough prizes to make the men take particular interest in their work. Below are given the rules for the annual inspection, which was made in November by the general superintendent accompanied by officers of the transportation, roadway, and bridge and building departments, and the superintendent. The Boston & Albany Ry. gave five prizes for division roadmasters and five (of $50 each) for section foremen, awarded on the following points: (1) Alinement and surface; (2) Joints and spiking; (3) Switches and frogs; (4) Ballast and ties; (5) Ditches and general neatness and cleanliness of roadway. The highest rating under each head was 10, which would mean perfection, and the inspectors marked according to their opinions. Stations, section houses, pump houses, water stations, etc., may be inspected in the same way. Sometimes every officer scores or marks for each item. In other cases a committee of two or more is appointed for each item. On long runs, there may be two committees for each item, working alternately by miles or sections, as it is not possible for a man to watch mile after mile of track in various conditions and form a reliable opinion as to its condition in various respects. It must be remembered that the foremen will naturally try to make their sections look particularly neat and well kept about the time of the inspection. Where the railway company does not offer premiums, this is sometimes done by the roadmaster in order to encourage his men to get and maintain good track. In one case of this kind a premium of $250 was awarded to the best section, of which $150 went to the foreman and the balance was divided among the laborers in proportion to the number of days worked by each man.

It is necessary to take into account the money expended upon each section

for material, tool equipment, extra gangs, etc. A section which has been improved at considerable expense may be expected to show a better appearance than one on which less extensive work has been done, yet the credit may not be due to the foreman. The awards should be so based that the greatest benefits go to the men who secure the best results per dollar of expenditure, and not merely to those who have the best track, without taking the expense into consideration. In the system adopted by one railway, five premiums were awarded as the results of the annual inspection: $100 to the supervisor of the best division; $50 to each of the two next best divisions; and $40 and $20 to the best and second best sections on each division. The section foremen were rated in three classes, according as the markings for their sections were over 8, over 6, or under 6. At the quarterly inspection, prizes were awarded on each division; $15 to the foreman showing the most improvement; $10 to the foreman having the smallest labor account without deterioration in the condition of his section (but if the section had previously received a low mark some improvement was required to obtain this award); $10 to the foreman making the best progress in bringing the roadbed and track up to the standard condition, and $10 for the foreman having the least expense for tools per man.

In the method formerly used by the Wabash Ry., the following rules were given, which included provision for expense account:

(1) Line.—True line means straight line on tangents, and uniform curvature on curves, as far as the eye can detect. When these requirements are fulfilled the condition must be represented by 10. Continuous and very apparent deviations from the true alinement over the entire length of one mile, which would limit the maximum speed for the safe passage of trains to 25 miles per hour, must be represented by 5. A condition of alinement which would be difficult for a train to pass would be recorded as 0. Intermediate conditions must be indicated in the proper ratio.

(2) Surface.—True surface means a uniform grade line between changes of grade, and the conditions must be noted as in regard to "Line."

(3) Level.—The inspector must watch the level index, and must note unusual oscillations of the car due to unlevel track on tangents, want of uniformity of elevation on curves, or unequal gage. If he can detect no vibration or oscillation he will record the condition as 10, and intermediate conditions must be recorded as already noted.

(4) Joints, Ties and Switches.—A perfect joint is one that is fully bolted and tight. Ties must be properly spaced, as per standard plan, and fully spiked with four spikes in each tie. Ends of ties on one side must be parallel with rail. Switches must be placed exactly as shown in standard specifications. When these are fulfilled the condition must be represented by 10.

(5) Drainage.—The ditches shall be uniform, free from obstruction, and with sufficient incline to afford proper drainage. Ballast shall be uniform and equally distributed. For perfect condition the marking is 10.

(6) Policing.—A perfect condition in all the following respects shall be represented by a marking of 10: Ties and rails must be piled according to the general rules. Grass, bushes and weeds should be kept cut close to the ground within limits of right-of-way, and not allowed to grow closer than within 6 ft. of the rails. Stumps and logs should be cleared from within limits of right-of-way. Road crossings must be in accordance with standard plans, and must be clear and safe for the passage of animals and vehicles. Signs must be placed in position as required in standard clearance diagram. Cross and line fences shall be kept in repair after being constructed by fence gang. They shall be of standard plans. Cross fences and cattleguards shall be clear of all grass and weeds, and shall be whitewashed.

Expense.—The section which is maintained at the least expense shall receive 10 points. The amount of expense on each section to be determined as follows: From the aggregate expense of the year shall be deducted the cost of

extra work, such as placing ties, rails, ballast, and ditching, for which credit will be made as follows: Ties in rock ballast credited at 20 cts. per tie; ties in gravel, cinder or earth ballast, 8 cts. per tie; rock ballast credited at $2.50 per car, other ballast at $1 per car; rail laid credited at $1.50 per 100 ft.; ditching, at $1 per 100 ft. After this deduction is made the section showing the least expense will be marked 100, which, divided by 10, will give the rating of that section. For each additional $10 of expense over the lowest section for all other sections, deduct one point from 100 points; the remainder, after being divided by 10, shall be the rating of that section regarding expenses on the general report, and shall be recorded as the average expense of all miles on that section.

District.	Section.	Miles.		Committee No. 1, 2 Persons.			Committee No. 2, 2 Persons.	Committee No. 3, 2 Persons.			Expense.	Remarks.
		Main Track.	Side Track.	Line.	Surface.	Sidings.	Joints and Ties. Switches in Main Track.	Drainage.	Policing. General.	Policing. Fences.		
...	...	...	...	.....	.....	.....	....	....	....	....	....	....
...	...	...	...	.....	.....	.....	....	....	....	....	....	....

(Wabash Ry.)

Maximum Rating..........			25	25	20	10	10	5	5	100	100
Division.	Section.	Miles.	Line and Surface.	Rail Joints, Spiking, Lining and Spacing Ties. Switc'es and Frogs.	Drainage and Ballast.	Old Material, Grass, Weeds, Right-of-way.	Houses and Gr'unds	Sidings.	Road Crossings and Fencing.	Average for Section.	Average for Division.
.....	.....	.....	.....	....	....	....	....	....	....	....	......
.....	.....	.....	.....	....	....	....	....	....	....	....	......

(Southern Pacific Ry.)

Fig. 211.—Scoring Cards for Track Inspection.

Special devices have been used to a very limited extent to give a visible indication of the condition of the track, such devices being intended for use on an inspection car or officer's car. Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., devised an instrument termed the equilibristat, which can be mounted in this way, and will show the difference in elevation of the rails by the difference in height of the liquid in the legs of a U-shaped tube set transversely to the track. The Chicago Great Western Ry. has a track indicator mounted in a car and used for indicating rough spots in the track. There are three long spring plates having one end fixed and the other end free; the latter carries a weight resting against a stop. Two of the plates are set on edge to record side swings, in opposite directions. The other is flat, to record vertical swings. A swing of the car causes the plate to move away from its stop and come in contact with another stop by which it closes an electric circuit. The circuit operates a magnet and needle which pricks a traveling roll of paper. The results are good when the car is

handled at a uniform speed, but are not reliable with fast running or slow running on curves. The dynagraph car, or recording car, for "mechanical inspection" has track connections which follow the irregularities in line, surface and gage. These, with low joints, superelevation of curves, deflection of rails, etc., are recorded in diagrams on rolls of paper. In some cases the low spots and the variations from true line are marked by jets of paint on the rail. This system has been applied to street-railway service by the Chicago City Ry. In most cases the mechanism is very complicated and costly, and is mounted in a large car.

The Ellis inspection machine, which has been tried on the Northern Pacific Ry., is small and simple, and is mounted on a three-wheel car weighing about 200 lbs. This can be attached to a hand car or inspection car, and can be operated at speeds up to 12 miles per hour. Each division may have its machine. The machine records on a continuous roll of paper a diagram showing the condition of the track as to line, and if the rails are level on tangents and have the proper superelevation on curves. It also records low joints (showing the amount of the depression) and all variations from the proper gage. On the machine is a wheel exactly 3 ft. in circumference, which is connected to a cyclometer and is used in making measurements. The lineal scale of the diagram is 200 ft. to the inch, or 26.41 ft. to the mile, with natural scale for the gage and half the natural scale for the elevation. The driving gear moves the paper over the roll at the rate of 26.41 ins. per mile of track. A pendulum moves to right or left as the wheel on either side goes higher than the other, thus moving the stylus to right or left. The paper has a heavy ruled line upon which the stylus follows when the track is perfectly level, and marks to the right or left of this line show how much it is out of level or what is the amount of elevation on curves. The paper is ruled with lines $\frac{1}{4}$-in. apart. A record of the gage is obtained by using an axle made of two pieces of tubing, one being large enough to admit the other. Inside the larger tube is placed a graduated spring which keeps the wheel flanges tight against the rails. The rod attached to the loose end of the axle carries the stylus which comes in contact with the paper and marks every change. A heavy line ruled on the paper shows where the stylus should be at standard gage, and the distance that the diagram drawn by the stylus varies from this line shows how much too wide or narrow the gage is at any point.

The Baltimore & Ohio Ry. has a track-inspection car or dynagraph car of the larger type. It is mounted on six-wheel trucks, and is attached to a locomotive, being run at a speed of 25 to 30 miles per hour. The speed is maintained as nearly uniform as possible. The diagram shows the condition in surface of the rails, the variation from gage, the transverse condition as to level or superelevation, and points where the car makes sudden side swings due to bad line. On the base line the position of mile posts, stations, etc., may be recorded. This is done by an observer by means of a push button. Another observer, at the recording table, makes the necessary notes on the paper. The rear truck has wheels with flat or cylindrical treads, and is not fitted with brakes. For measuring the surface condition, there is a 5-in. I-beam over each side sill of the truck, supported by columns $10\frac{1}{2}$ ft. apart which rest on the journal boxes of the first and third axles. On the middle axle box are plates sliding vertically in yokes attached to the I-beam. Two electrical contacts record variations of $\frac{3}{8}$-in. and over, and $\frac{5}{8}$-in. and over. The

gage condition is measured by means of a pair of 18-in. wheels with flat treads and sharp flanges; these are attached to shafts in a yoke behind the rear truck, and the yoke can be raised clear of the track by a pneumatic cylinder. Springs force the wheel flanges against the rails, and wire connections transmit the relative movements of the two wheels to the levers which operate the recording pencil. The transverse relation of the rails is indicated by means of a heavy pendulum suspended under the recording table and moving in a tank of thick oil; a system of levers connects the pendulum with the pencil. For recording sudden swings, there is another pendulum, having its upper end above the table, and connected to copper balls which normally lie against it. A sudden swing causes these to fly out and strike a fine copper wire, making an electrical contact which actuates the electromagnet of the pencil, causing it to make a mark on the line. Connected to the apparatus are three valves and nozzles; from two of these a 6-in. to 12-in. streak of whitewash is marked on the rails to indicate low spots, while a jet of yellow paint from the third indicates a bad swing in line. The car is used for the annual inspection, the record being used as a basis for the tabulation of conditions on each division, while a carbon copy of the record is sent to the division engineer. Before being used, the apparatus is calibrated and adjusted by running it on a level piece of track having exact gage. In a car used at one time by the University of Illinois and operated on the Cleveland, Cincinnati, Chicago & St. Louis Ry., the motions were transmitted by oil under pressure in pipes connecting the receiving and recording cylinders. The piston rods of the latter carried the recording pencils.

The most completely equipped track-inspection dynagraph car, and the most comprehensive system of records, are those designed by Mr. P. H. Dudley. He operates his car, and makes occasional or periodical inspections for railways, submitting reports based upon the autographic records. The advantages of such inspection for ascertaining the general condition of track and its comparative condition (by comparing diagrams taken at different times) can hardly be overestimated, and his work aided very materially in bringing the tracks of the New York Central Ry. and Boston & Albany Ry. to the high degree of perfection for which they are noted. The diagrams show the results obtained by new rails and other improvements, the relative economy of which can be thus determined. The work required on the several sections can be seen at once, while the section foremen have their attention called to low joints, low spots, etc., the machine marking deflections ⅛-in. or ¼-in. below the normal surface. The foremen are not governed entirely by this in surfacing, but know that every paint mark means a weak spot, and that even if the rail appears to be in surface, the ties may be loose and working up and down in the ballast, or the spikes may be loose, and allow the rail to stand free from the tie. These defects they could not detect by sighting for surface. The car has wheel loads of 6,500 lbs. and a special six-wheel truck of 11-ft. wheelbase. It is run at a speed of about 30 miles per hour, and each rail records autographically (as a continuous diagram) its condition as to surface, due to the steel, ties, ballast, roadbed and labor. The various undulations are mechanically summed up by the apparatus. Three examples of the Dudley dynagraph diagrams (to a reduced scale) are shown herewith. Fig. 212 is from track laid with 80-lb. rails, 5¼ ins. high, having three-tie joints; this track is in excellent condition. Fig. 213 is from track laid with older 80-lb.

rails, 5 ins. high, also with three-tie joints; these rails were not straightened properly at the mill and had a wavy surface. Fig. 214 is a portion of the com-

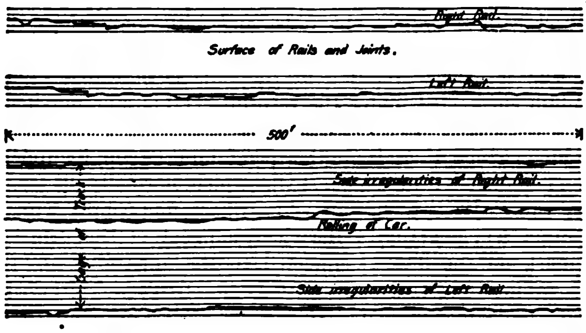


Fig. 212.—Track Diagram of Dynagraph Car; Good 80-lb. Rails.

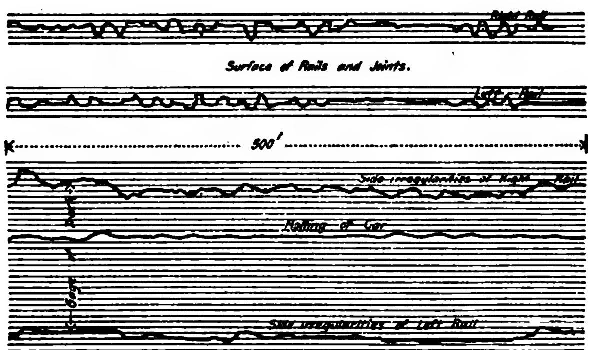


Fig. 213.—Track Diagram of Dynagraph Car; Old 80-lb. Rails.

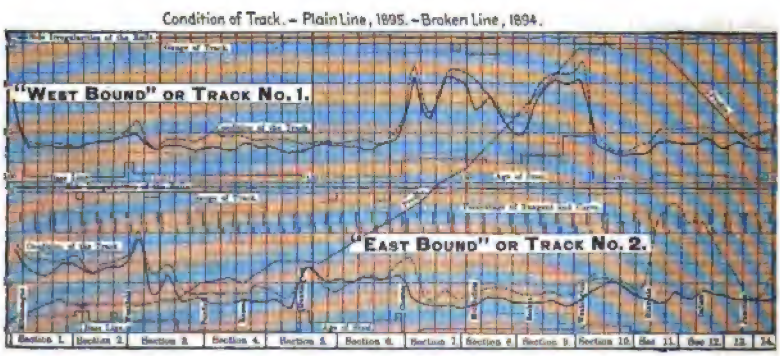


Fig. 214.—Diagram of Comparative Condition of Track of Boston & Albany Ry.; 1894–95.

plete maintenance-of-way diagram plotted from the autographic records. This diagram is for a portion of the Boston & Albany Ry., and compares the

condition of the track as shown by the dynagraph-car inspections in 1894 and 1895. The following explanation accompanies the diagram.

The spaces between the vertical lines represent miles of road. The line marked "Condition of Track" for each inspection represents the average sum of all the various undulations of the rails per mile, as mechanically summed up by the inspection apparatus. To plot the sum of the undulations on the diagrams, the number of inches per mile is divided by 176 (the number of 30-ft. rails per mile), which gives the average undulations per rail per mile to 0.01-in. Each horizontal line on the diagrams represents 0.01-in. The results for each track are relative to the base line, yet are comparative one mile with another. The average condition of each mile is indicated from the horizontal line crossed or touched by the "Condition-of-Track" line in the center of the space for the mile.

The line marked "Age of Steel" for each mile gives the length of service, each horizontal line representing one year. The line marked "Percentage of Tangent and Curve" shows the approximate alinement of both tracks per mile. The percentage of tangent is marked on the left side of the space for the mile, and that of the curvature on the right side. Each horizontal line represents 10% for the mile. The line marked "Profile" shows the grades of the road, and is common to both tracks, though ascending grades on one track are descending upon the other, and vice versa. Each horizontal line represents 10 ft. of elevation.

The line marked "Gage of Track" reads downward from the Base, or 70th line, and shows the amount the track is wide gage, each horizontal line representing 1/10-in. Nearly every mile now shows a perfect gage. For the line marked "Side Irregularities of Rails," above the 70th line, each horizontal line represents 1/10-in. This line reads from the highest point in the center of the space for the mile. These lines show about the best results which can be obtained.

CHAPTER 24.—SWITCH WORK AND TURNOUTS.

To divert a train from one track to another a turnout is used, which is essentially a curve connecting the diverging tracks. This curve, however, is built up of (1) a switch to direct the train onto one or other of the tracks as desired, (2) a frog to allow wheel flanges to pass the intersection of the rails, and (3) lead rails connecting the frog and switch. A crossover consists of two turnouts and a short piece of diagonal track, forming a connection between two parallel tracks. A ladder track is diagonal to a series of parallel tracks which are connected with it by turnouts. In all these arrangements, the turnout is the important feature. The lead is that part of the main-track rail from the point of switch to the point of frog. The turnout curve (or lead curve) is that of the turnout rail between the same points. For calculating the length of lead, the turnout curve may be assumed to extend from point of switch to point of frog, giving what is termed the "theoretical" lead. This is too long for ordinary main-track frogs (over No. 7) and flattens the curve at the switch. The reason for this is that the switch rail, being of considerable width, and being necessarily set to allow sufficient flangeway space at the heel, cannot be placed in the theoretical line of the curve, but lies several inches within it at the heel. The more general practice, therefore, is to assume that the turnout curve extends from the heel of the switch to the point of frog. This gives what is termed the "short lead." Below are given simple formulas for cal-

culating the lead: G=gage of track; N=number of frog; T=throw of switch; L=length of switch rail; F=length of frog from point to toe.

(1) Theoretical lead $= G \times 2 \times N$.
(2) Short lead $= 2N(G - \sqrt{GT}) + L$.
(3) Short lead $= 6N + (L + F)$.

Frogs of the same number but of different lengths will have slightly different curves; as will also split and stub switches with the same frogs. The length of lead is practically the same for turnouts from curved track as for those from tangents, and it is of no effect to increase the lead, with the idea of reducing the curvature of the turnout, unless a higher frog number corresponding to the longer lead is used. The curvature of the turnout curve varies on curves: (1) When the turnout is from the inside of a curve, its degree of curvature will be the sum of the degrees of the turnout curve and the main-track curve; (2) When the turnout is from the outside of a curve, its degree of curvature will be the difference between the degrees of the two curves. Thus with a No. 10 frog, the curvature of a turnout curve from a tangent will be 6°; from the inside of a 3° curve, it will be 6°+3°=9°; from the outside of a 3° curve, it will be 6°−3°=3°. Where the turnout is on the inside of a main-track curve, the frog number should be as high as possible, to keep the degree of curve as small as possible. The curves of main-track turnouts are usually 8° to 6°, with frogs of Nos. 9 and 10. The maximum is about 20° with No. 6, but such frogs should not be allowed in ordinary main tracks. With locomotives having six or eight driving wheels, all flanged, there is likely to be trouble on curves of less than 6°, the lead curve being distorted, and the lead beyond the frog spread so as to cause derailment of cars. With No. 12 and No. 20 frogs at the ends of double track, where trains run at high speed, the curve will be about 4½° to 1½°. If the length of the switch rail is divided by the difference between the width of its point and the distance between gage lines at the heel, the result will be the "switch number," a function which Mr. W. B. Lee has used in the formulas for short leads given below. The distance between the actual and theoretical points is equal to the width of the former multiplied by the switch number. For any given switch and frog there is only one radius for the arc of a circle which will connect the heel of switch and toe of frog and be tangent at those points, and it is also the maximum. This will be seen from Fig. 215; for if the switch is moved toward the frog, it shortens the

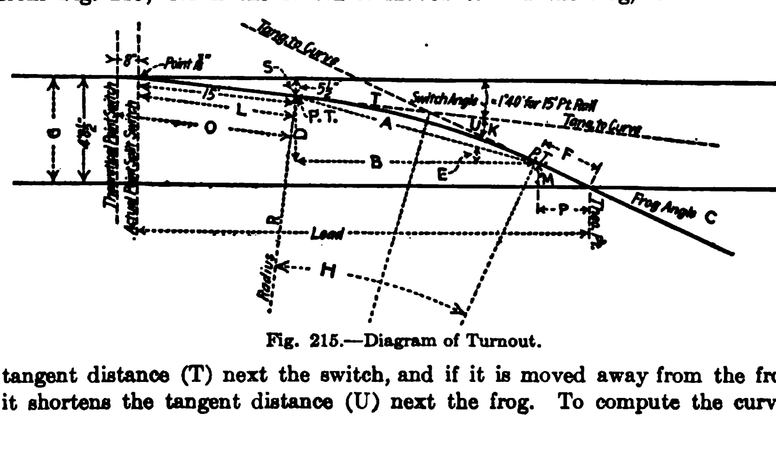


Fig. 215.—Diagram of Turnout.

tangent distance (T) next the switch, and if it is moved away from the frog, it shortens the tangent distance (U) next the frog. To compute the curved

and straight leads (A) and (B) and the radius (R) by exact methods requires the use of trigonometrical functions and preferably a table of logarithms, and these methods are generally used for very exact work. Mr. Lee, however, has developed the following arithmetical formulas, which give closely accurate results. With a No. 14 frog, the error is 1-in. in lead and 6 ins. in radius. The error decreases until for a No. 10 frog it is only 1/16-in. and $1\frac{3}{4}$-ins. respectively.

(4) $X = O + S$.	(7) $N = F + M$.
(5) $D = G - (S + M)$.	(8) $B = \sqrt{A^2 - D^2}$.
(6) $A = 2D\dfrac{XN}{X + N}$.	(9) $R = A\dfrac{XN}{X - N}$.

The nomenclature for these formulas, and indicated on the diagram, is as follows: A = Length of turnout curve; B = Length of straight rail; C = Frog angle; D = Perpendicular distance from heel of switch to toe of frog; E = Angle of chord A with B; F = Length of turnout side of frog from theoretical point to toe; G = Gage of track; H = Closure of arc; J = Switch angle; K = Intersection angle; L = Length of switch rail; M = Spread of frog at toe (between gage lines); N = Frog number; O = Distance from heel of switch to theoretical point; P = Length of straight wing of frog; R = Radius of turnout curve; (S) = Spread of switch; T = Tangent from switch; U = Tangent from frog; X = Switch number. The diagram, Fig. 215, shows a switch with a 15-ft. rail, a spread of $5\frac{1}{2}$ ins. at the heel, and a switch angle of 1° 40′. Some other formulas relating to this diagram are given below:

(10) Angle K = C − J.	(14) Distance M = F × sine C.
(11) Angle E = C − $\frac{1}{2}$K.	(15) Distance A = D + sine E.
(12) Lead = L + B + P.	(16) Distance B = D + tan E.
(13) Closure = Arc H.	(17) Radius = $\frac{1}{2}$A + sine $\frac{1}{2}$K.

The divergence of the turnout is given by formula No. 7 under "Curves." The Hocking Valley Ry. gives the following rules:

(1) To find the distance K from origin of curve to point of frog.—Multiply twice the gage by the frog number.

(2) To find the radius of turnout curve.—Square the distance K and divide it by twice the gage.

(3) To find length of switch rail.—Square the radius; then square the radius minus the throw of switch; subtract the latter from the former and extract the square root.

(4) To find the distance between the frog points of a crossover (measured parallel to the tracks) when the tracks are straight and parallel.—Subtract twice the gage from the distance c. to c. of tracks, and multiply the remainder by the frog number. Thus for No. 8 frogs and tracks 13 ft. c. to c. it will be: (13 ft. − 9 ft. 5 ins.) × 8 = 28 ft. 8 ins.

In Fig. 216, the three lower diagrams (213, 214 and 215) represent the elements of turnouts: KC is the lead, or tangent distance from headblock to frog point; DCE is the frog angle; and O is the crotch frog (for a three-throw switch), which is 7/10 of the frog angle DCE. It will be seen that the turnout rails should conform to a curve tangent to the main and turnout tracks. If the turnout leaves a straight main track, the frog angle DCE will equal the intersection angle CPM, and the central angle BAC. The turnout curve must be one fitting the tangents QP and PC. When the main track is curved, and the turnout curves in the opposite direction, the frog angle DCE will be equal to the sum of the central angles ABC and BAC (= FCB). When

the main and turnout curves are in the same direction, the frog angle DCE will be equal to the difference between the central angles CHG and CAG (= ACH). The latter arrangement should be avoided wherever practicable, as it sharpens the frog angle, which is always undesirable. With a split switch, the lead KC is from the point of the turnout. With a stub switch, the lead (called also stub lead) is from the headblock, differing from the point lead by the length of the moving rail. As a matter of fact, however, the split switch rail cannot be so thrown as to conform to the theoretical curve if made 15 ft. long, with the splice joint as the hinge. The switch rail is usually taken as a straight line, so that as in Fig. 216 (diagram 216) the intersection angle, RSP, will not be the same as the frog angle, but will be the frog angle minus the switch angle. In other words, the curve must fit the tangents RS and SC, instead of the tangents QP and PC.

The switch rail, as already noted, cannot be placed in the theoretical line. Neither can it be planed to a knife edge, but is usually about ¼-in. thick at

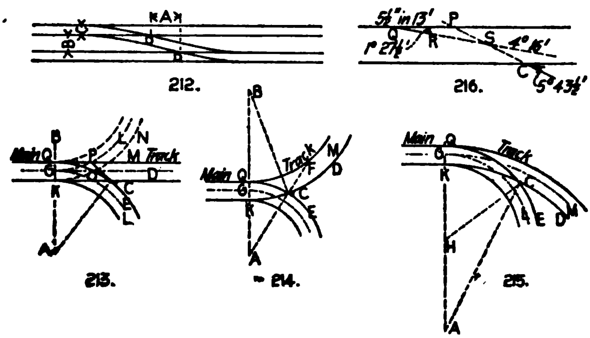


Fig. 216.—Diagrams of Switch Work.

the end. The actual point is 12 to 18 ins. from the theoretical point, but trackmen are apt to set it too close to the latter. At the theoretical point, the stock rail should be bent to conform as nearly as possible to the switch angle. The Southern Pacific Ry. requires that a distinct bend be made with a rail bender (care being taken not to simply spring the rail to a curve), so that when the switch rail is laid close against the stock rail and with its point 16 ins. from the bend, the gage side of switch rail and stock rail will be in alinement. A turnout has a theoretical curve tangent to the frog point and the opposite rail. In practice, the curve is from the toe of the frog to the heel of the switch, and is of somewhat shorter radius than the theoretical curve. Where the curve extends beyond the frog (as for a Y track), it will generally be sharper than the turnout curve, in order to save room. Thus with a No. 10 frog, the turnout curve would be 5° 3′, while the curve beyond might be 10° to 12°.

As the frog is straight, it forms a kink or short tangent in the turnout curve. In early practice, trackmen would sometimes spring the wing rail to conform approximately to the curve, but with modern heavy frogs this is practically impossible, and it is forbidden by some roads. It was done by setting the main wing in line with the straight main rail, and bending the end of the other wing by spiking so as to fit the turnout curve. Most men, however, would

naturally put in a frog without alteration and fit the curve to it. The kink is of little importance at low speeds, but it has been suggested that it might be well to curve the frogs for crossovers of four-track roads through which trains run at high speeds. The frog being a tangent, this tangent should be continued beyond the heel of frog for about 12 ft. for a No. 6 frog to 30 ft. for a No. 15 frog, in order to make an easy riding turnout. This length is the same as the length of tangent in a crossover. In locating sidings, the point of curve back of the frog is assumed at the frog point, and the line is started from the frog and not from the point of switch. If the main line should be a curve in the same direction as the turnout, the frog is then a short tangent between two curves, on one of which it is impracticable to give elevation for curvature, and therefore slow speed is necessary. If the location of the frog point is fixed first, and the frog angle is turned from the main line or from a tangent to the main line at that point, the turnout can be run as easily as any other curve. A table of leads and turnout curves for straight track can be constructed, considering the frog (from heel to toe) as one tangent, and the switch rail as another, and calculating the circular curve required to connect them. Then calculate the offset between the main line and the turnout curve at a point half way between the frog point and heel of switch rail (or headblock for stub switches). This offset will be the same for the same frog, whether the turnout be on either side of the tangent, spiral, or simple or compound circular curve. It should be used in staking out the lead, as it saves the trouble of determining the degree of the turnout curve in the last three cases. In three-throw switches, the distance from the crotch frog to the main frog is 0.3 $\times$ theoretical lead; or approximately 3 $\times$ frog number. In putting in the crotch frog of a three-throw switch, when both of the side frogs are of the same number, put in one lead first and line it up properly. Then take the track gage and move it along the track until the center point is over the center of the lead rail, which will be the place for the point of the crotch frog.

The method of putting in turnouts by offsets from the main rail is shown by Table No. 36 and Fig. 217. The distances given are measured from the

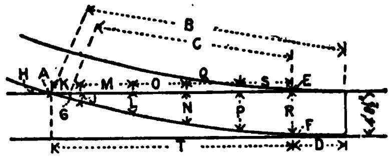


Fig. 217.—Diagram for Turnout Measurements.

gage side of the rail head. They may be used on curved as well as straight track, provided the curve is regular. The main track should be set to true line before the frog is put in. The measurements are calculated from the theoretical point of frog, but are changed to give the correct distances from the actual point. On the standard plans of the New York Central Ry., the distance on straight rail between heel of switch and theoretical point of frog is divided into four parts and the offsets (between gage sides of rails) are given on the convex side of the turnout. The spread at the heel is 6 ins. (7 ins. in a No. 20 frog), and the fourth ordinate (at the frog point) is 4 ft. 9 ins. The intermediates range from $12\frac{3}{8}$ ins., 23 ins., and $37\frac{7}{8}$ ins. for a turnout with No.

7 frog; to 13½ ins., 24½ ins., and 39 ins. for one with a No. 14 frog. The lead is 61 ft. 8 ins. for the former and 107 ft. 11½ ins. for the latter, exclusive of the switch rails. These are 15 ft. long up to No. 13, 20 ft. for No. 14, and 30 ft. for No. 20.

To set out the turnout curve, stretch a cord from the theoretical point of frog (as measured from K, Fig. 216, diagram 215, and marked on rail), to the point of curve QC or RC, allowing for proper spread of switch-rail heel. Divide this distance into four parts, and (for standard gage) set off a middle ordinate of 1.177 ft. and two side ordinates of 0.883 ft. These are on the concave side of the turnout. From each of these points, and from the frog point and point of turnout, measure half the gage, which will give five points on the center line of the turnout curve. Each side ordinate is 3/4 of the middle ordinate. At the middle point of the lead the offset from main rail to turnout rail (gage to gage) is always 1/4 the gage, and at the quarter points it is 1/16 and 9/16 the gage, whatever may be the frog number, length or lead, or whether the turnout is from a tangent or curve. The degree of the turnout curve is 600 divided by the square of the frog number (approximately) when the turnout is from a tangent, and this, plus or minus the degree of main curve, gives the degree when the turnout is from the inside or outside of a main-line curve. The middle ordinate for bending 30-ft. rails is 12 ÷ square of frog number more (or less) than the main-curve ordinate, and for other rail lengths, it is in proportion to the square of the respective lengths. If the degree (D) of turnout curve is known, the middle ordinate of a 30-ft. rail is 0.02D.

TABLE NO. 36.—LAYING OUT TURNOUTS BY OFFSETS.

Frog		Rigid.	Spring.	Spring.	Spring.
Frog number		6	8	10	12
Frog angle	A	9° 32′	7° 10′	5° 44′	4° 47′
Clearance of heel of switch	F	5½ ins.	5½ ins.	5½ ins.	5½ ins.
Length of switch rail	D	15 ft.	15 ft.	15 ft.	15 ft.
Point of switch to point of frog	B	56 ft. 4¾ ins.	65 ft. 6⅞ ins.	76 ft. 8¼ ins.	86 ft. 9 ins.
Heel of switch to frog point*	T	41 " 4¾ "	50 " 6⅞ "	61 " 8⅝ "	71 " 9 "
Lead curve		20° 26′	12° 38′	7° 20′	4° 43′
Offset from main rail to lead	J	5½ ins.	10⅞ ins.	8½ ins.	7 ins.
" " " " " "	L	1 ft. 7¾ ins.	2 ft. 4½ ins.	1 ft. 7 ins.	1 ft. 10 ins.
" " " " " "	N	3 " 4⅝ "	3 " 6½ "	2 " 9⅝ "	2 " 10½ "
" " " " " "	P	....	....	3 " 1⅝ "	3 " 8 "
" " " " " "	R	4 ft. 3 ins.	4 ft. 3 ins.	4 " 3 "	4 " 3 "
Distance, frog point to offset	K	3 " 0 "	7 " 6 "	7 " 6 "	7 " 6 "
" " " " "	KM	11 " 4¾ "	20 " 6 "	16 " 8⅝ "	23 " 9 "
" " " " "	KMO	26 " 4¾ "	35 " 6 "	31 " 8⅝ "	39 " 9 "
" " " " "	KMOQ	....	....	46 " 8⅝ "	55 " 9 "
" " " " "	KMOQS	41 ft. 4¾ ins.	50 ft. 6 ins.	61 " 8⅝ "	71 " 9 "

* Measured along the rail.

Single switches or turnouts may be put in by measurements only, but for anything more than this, the transit should be used, setting stakes for points of switches and frogs, and for the reverse and tangent points. Where a number of parallel tracks are to be put in, it is customary to stake out the first one, and put in the others by measurement from this. It is always best, however, to set out main-line turnouts and turnouts from curves with the transit. The Dunn indicator is a device for showing the angle, lead, frog number, lead radius, etc., for turnouts with ordinary and slip switches or special frogs. It is on the principle of the sextant, and consists of two graduated sector plates pivoted at one end and sliding over each other, the figures on the lower plate being seen through the apertures in the upper plate. This is used for convenience in obtaining the necessary detailed information as to any given turnout.

When putting in an ordinary turnout, the exact point of commencement is rarely fixed arbitrarily, but may be so located that the heel or toe of the frog can be attached at a rail joint, thus preventing one cutting of the rail. Fig. 218 shows the arrangement adopted by the Southern Pacific Ry. to prevent cutting the rail. Main-line rails should never be cut for temporary sidings. From the point selected, measure along the main or straight rail the distance from heel of switch to the theoretical frog point, and mark the rail with chalk. Then from this mark measure the distance to the heel of switch as given by the table. From the heel the distance c. to c. of ties is marked on the rail flange to facilitate laying. The fact that close accuracy or fine work is not necessary in practical work is recognized on many roads, and the switch dia-

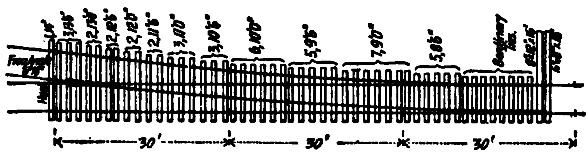


Fig. 218.—Method of Putting in a Split Switch without Cutting Rails; Southern Pacific Ry.

grams of the Atchison, Topeka & Santa Fé Ry. bear the note that the location of any frog may be varied a foot or two when such change will avoid the cutting of a rail. The practice of the Baltimore & Ohio Ry. in laying turnouts is described at the end of this chapter.

The actual length of lead is a matter of minor importance for ordinary work and simple turnouts, and may be varied several inches (or even feet) to avoid cutting rails or for other reasons of practical convenience. The reason is that the rails, being of measurable width, cannot be laid exactly to follow the theoretical lines or center lines, so that a little variation more or less in either direction makes practically no difference in the turnout. When putting in turnouts with short leads, it is only necessary to be careful to place the frog point opposite the stake, letting the switch point come where it may. This in no way disturbs the alinement behind the frog. The short leads may be shortened to economize in cutting the rails to fill in between the switch and frog. For instance, a turnout with a No. 8 frog may be laid with a 15-ft. switch rail, a 30-ft. rail, and 15-ft. piece, which with a 15-ft. frog gives a lead of 67 ft. Two pieces 15 ft. 1 in. and 14 ft. 11 ins. long can be made from a 30-ft. rail, and by putting the shorter piece on the straight lead and the longer piece on the curve, the switch points are kept square across the track. Many roads specify that with spring-rail frogs the turnout wing rail must be 2 ins. longer than the main-line rail (measured from the point), in order to bring the switch points square to the track with the same length of closure rails on both straight and curved leads. In a No. 9 spring-rail frog 15 ft. long, the closures will be 50 ft. and 49 ft. 9¾ ins. By making the turnout wing 2¼ ins. longer than the main-line wing, the closure rails can be made the same length. This may be important, as for a No. 10 frog, where two 30-ft. rails sometimes form each closure.

In building turnouts it is very desirable to utilize rails of such lengths as are generally available, and to avoid the cutting of special lengths which will cause waste. In the design of the standard turnouts for the Chicago, Rock Island & Pacific Ry., this has been kept in mind, and lengths of lead have been adopted which will permit of the maximum length of curve between

toe of frog and heel of switch, and which at the same time will permit the use of ordinary lengths of rail. This is shown in Table No. 37. With the No. 15 frog at the end of a double-track section, with tracks 13 ft. c. to c., the straight line of turnout extends 60 ft. 4¼ ins. beyond point of frog (75 ft. 5¼ ins. for tracks 14 ft. c. to c.); this is followed by a 3° curve 127.23 ft. long, turning an angle of 3° 49′ and running into the second track.

TABLE NO. 37.—TURNOUTS AND LEAD RAILS; CHICAGO, ROCK ISLAND & PACIFIC RY.

Frog No.	Switch rail.	Sw. pt to bend in stock rail.	Angle bet. c. lines of tracks.	Pt. of switch to intersec. of c. lines.	Pt. of switch to pt. of frog.	Heel of switch to toe of frog. Straight.	Curved.	Radius.
	ft.	ins.	deg. min.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	deg. min.
6	15	11	9 32	28 10⅝ (28.89)	57 4 7/16 (57.37)	38 10 7/16 (38.87)	39 1 9/16 (39.13)	21 14
7	15	11	8 10	28 7 5/16 (28.61)	61 10 9/16 (61.88)	41 10 9/16 (41.88)	42 1 7/16 (42.12)	15 47
8	15	11	7 9	30 0	68 0	48 0	48 2¾ (48.23)	11 45
10 Sp. r.	15	11	5 44	30 2⅞ (30.24)	77 8 (77.67)	56 0	Sp. 56 0 Rig. 56 2	7 18
15	24	17½	3 49	50 0⅞	121 4¼ (121.35)	89 10¼ (89.85)	90 0	3 7

Lead Rails.—No. 6: (A) 2–26 ft. and 1–26 ft. cut to 13 ft. 1 9/16 ins. and 12 ft. 10 7/16 ins. (B) 2–28 ft., 1–22 ft. (11 ft. 1 9/16 ins. and 10 ft. 10 7/16 ins.). (C) 2–24 ft., 1–30 ft. (15 ft. 1 9/16 ins. and 14 ft. 10 7/16 ins.).

No. 7: (A) 2–28 ft., 1–28 ft. (14 ft. 1 7/16 ins. and 13 ft. 10 9/16 ins.). (B) 2–30 ft., 1–24 ft. (12 ft. 1 7/16 ins. and 11 ft. 10 9/16 ins.).

No. 8: 3–24 ft. and 1–26 ft. cut to 24 ft. 2¾ ins.

No. 10: (A) 2–30 ft. and 2–26 ft. (B) 4–28 ft.

For complicated yard work, junctions, etc., close calculation and measurement are required, as any variation in one part will affect the entire layout. The same is true of street-railway work, much of which is built up at the shops and sent out so that it can be assembled and riveted or bolted up in the field with the same accuracy as that required for steel bridge work. In laying out yards, shop tracks, terminal connections and complicated work, it is best to plot the plan on a large scale, and then take off the leads, etc., from the drawing. The following method was adopted in planning and ordering the material for ties, frogs, switches, etc., and in setting out the work for the trackmen, at the Southern terminal station in Boston, where the tracks are unusually complex, as described in Chapter 13. A plan was drawn to a scale of ¼-in. to 1 ft., upon which was a center base line, with 100-ft. stations. Points at right angles to this base line were designated as so much east or west of certain base-line stations. This plan was developed to show each tie (and its length), each special timber support for any part of the interlocking apparatus, each switch, frog, guard rail, etc., the station and distance east or west for each switch point and frog point, the point of curve and radius for each piece of curved track, also all signal posts and signal bridge supports, as well as all grades. From this plan all ties and special timbers were ordered, it having been carefully examined for the latter purpose by the signal company. The entire plan was about 24×7 ft., divided into several sheets, and was upon tracing cloth for purpose of blue-printing. All of the calculations for this work were made and checked in the office so that the setting out was a careful reproduction with the transit and tape of just what was on the plan, using ordinary stakes for line. Later on, when the tracks were raised to grade upon the bal-

last, grade stakes were set. Methods of laying out yard tracks were described in "Engineering News," March 28, 1901.

The details of turnouts and switch work will be found in many field books, and in Lovell's "Practical Switch Work" and Torrey's "Switch Layouts," and are not intended to be dealt with in this book (see also "Engineering News," March 28, 1901; April 3, 1902; and Sept. 8, 1904). The work is often regarded as a very complicated and difficult operation, due largely to the number of formulas and calculations which have been devised. In practical work, however, there is little to choose between these, and a good turnout may be laid out by almost any of the innumerable formulas and tables, for the reason that (within quite wide limits) it makes no particular difference what is the actual length of the turnout lead. In this connection is quoted the following simple and concise statement on "The Art and Mystery of Laying Out Turnout Curves," written by the late Mr. Wellington some years ago:

The theoretical lead for standard gage = No. of frog × twice gage, = 9.42 × No. of frog. This assumes the curve to be a simple circular arc, which is not essential for a good curve, nor does it give the best, and considers the curve to extend back to the heel of the switch rail of a stub switch. The lead is always the same, whether the turnout be from a tangent or a curve. A difference of not exceeding 10% in length of lead, especially if the lead be made longer than above, has no appreciable injurious effect on the character of the turnout curve or on its radius. This is best seen by calling the turnout curve a parabola, and remembering that whether the tangents of a parabola be equal, or one 20% longer than the other, will not affect the excellence of the curve, nor, materially, the sharpest radius. Whether the curve be called a circle or a parabola will not alter its position on the ground by more than a hair's-breadth.

To lay out the turnout curve, the frog being in place, and length of lead given, not differing more than 10% from the theoretical lead. Practically, the best transit for running in the curve, and the only one much used for fixing points on it, is an experienced eye. On all kinds of turnout curves, whether from straight or curved main track: Offset from gage side of main rail to gage side of lead rail at middle point of lead = ¼ gage, or 14 ins.; offset at ¼ point of lead = 1/16 gage, or 3½ ins.; offset at ¾ point of lead = 9/16 gage, or 31¾ ins.

Split Switches.—The gage side of the split rail is straight; therefore it can only be considered, when in place, as a tangent to the true turnout curve. The point at which the theoretical turnout curve attains an offset of the width of a rail head (say 2¼ ins.) from the main line is 0.8 of the theoretical lead from the frog. Hence to obtain the same turnout curve with a split switch as with a stub switch, the lead should be (0.8 × 9.42 × N) or 7.54 × N + the length of the plain portion of the head of the point rail. Split-switch leads, in other words, other things being equal, should be a little shorter than stub-switch leads. But as all turnout curves are improved by being a little longer than a simple circular arc requires, a lead fixed by the rule of 9.4 × N is good practice for split switches.

Radius.—By the principle of proportional triangles, the radius = lead × No. of frog = (No. of frog)^2 × gage. This holds only on turnouts from tangents.

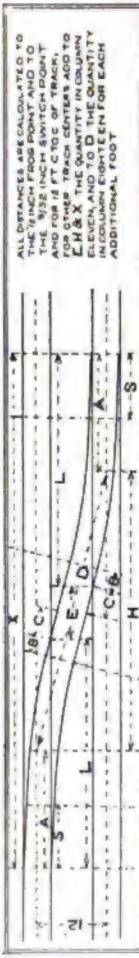
Degree of Turnout Curve.—The frog angle = 57° (or 3420 mins.) ÷ Frog number. The degree of turnout curve =

$$\frac{\text{Frog angle}}{\text{Lead in stations of 100 ft.}};\ \frac{57^\circ}{N} + \frac{2Ng}{100} = \frac{606}{N^2},$$

or, in round numbers, 600 ÷ square of the number of the frog. If the turnout be from a curved main track, add to the degree thus obtained the degree of the main curve, if the turnout is to the inside of the curve; and subtract it, if to the outside.

Most railways have standard plans and tables of turnouts, and Table No. 38 has been compiled from the diagrams of the New York, New Haven &

Hartford Ry. The reference letters are given on Fig. 217. The switch rails are all 15 ft. long, except for turnouts with No. 15 frogs; these are 24 ft. long, 14 ft. being straight and 10 ft. on the turnout curve. All the switches have a throw of 3¾ ins. The rigid frogs have a spread of 5 ins. at the toe (G), and 10 ins. at the heel (H), while the spring-rail frogs have a spread (G) of 9⅝ ins. All ties are 7 × 9 ins. The guard rails are 15 ft. long, being straight for 9 ft.,



No.	Length B+C	Toe to ½" point B	½" point to heel C	Length of switch rail S	Heel spread	Frog angle	E	H	X	Correction E H&X	Degree of curve	Lead on line A	Lead L	Angle of switch rail	Heel spread	Distance D	Correction for D per foot	No.	Exact calculated lead
4	8	3'-0"	5'-0"	11'-0"	5½"	14°15'00"	9.250	47.250	89.250	3.938	45°35'33"	21.000	40'-0"	2°15'51"	7⅞"	48.750	4.063	4	38.395
4½	8	3'-0"	5'-0"	11'-0"	5½"	12°40'49"	10.584	53.334	93.584	4.444	37°50'00"	20.125	41'-6"	2°15'51"	7⅞"	54.667	4.556	4½	41.637
5	8	3'-0"	5'-0"	11'-0"	5½"	11°25'16"	11.900	59.400	103.900	4.950	29°48'38"	22.250	46'-0"	2°15'51"	7⅞"	60.600	5.050	5	44.757
6	8	3'-0"	5'-0"	16'-6"	6½"	9°31'39"	14.500	71.498	128.500	5.958	20°38'37"	28.500	57'-0"	1°47'56"	9"	72.498	6.042	6	56.891
6	8	3'-0"	5'-0"	15'-0"	6½"	9°31'39"	14.500	71.498	122.500	5.958	20°28'54"	25.500	54'-0"	1°58'43"	8 1/16"	72.498	6.042	6	54.802
6	8	3'-0"	5'-0"	13'-0"	5½"	9°31'39"	14.500	71.498	122.500	5.958	20°05'04"	25.500	54'-0"	1°54'58"	8⅝"	72.498	6.042	6	53.836
7	15	6'-6"	8'-6"	16'-6"	6½"	8°10'16"	17.073	83.573	138.073	6.964	16°54'00"	27.250	60'-6"	1°47'56"	9"	84.430	7.036	7	60.581
7	15	6'-6"	8'-6"	15'-0"	6½"	8°10'16"	17.073	83.573	138.073	6.964	16°43'46"	27.250	60'-6"	1°58'43"	8 1/16"	84.430	7.036	7	58.421
7	8	3'-0"	5'-0"	15'-0"	6½"	8°10'16"	17.073	83.573	138.073	6.964	14°30'58"	27.250	60'-6"	1°58'43"	8 1/16"	84.430	7.036	7	60.558
7	8	3'-0"	5'-0"	13'-0"	5½"	8°10'16"	17.073	83.573	138.073	6.964	14°15'25"	27.250	60'-6"	1°54'58"	8⅝"	84.430	7.036	7	59.768
8	10	4'-0"	6'-0"	16'-6"	6½"	7°09'10"	19.625	95.623	155.364	7.969	11°16'40"	29.870	67'-0"	1°47'56"	9"	96.374	8.031	8	67.869
8	15	6'-6"	8'-6"	16'-6"	6½"	7°09'10"	19.625	95.623	151.625	7.969	12°18'08"	28.001	67'-0"	1°47'56"	9"	96.374	8.031	8	66.370
8	15	6'-6"	8'-6"	15'-0"	6½"	7°09'10"	19.625	95.623	146.625	7.969	12°08'11"	25.501	63'-6"	1°58'43"	8 1/16"	96.374	8.031	8	64.015
8	15	6'-6"	8'-6"	13'-0"	5½"	7°09'10"	19.625	95.623	146.625	7.969	11°54'22"	25.501	63'-6"	1°54'58"	8⅝"	96.374	8.031	8	63.361
10	15	6'-6"	8'-6"	16'-6"	6½"	5°43'29"	24.702	119.702	178.702	9.975	7°12'12"	29.500	77'-0"	1°47'56"	9"	120.302	10.025	10	77.250
10	15	6'-6"	8'-6"	15'-0"	6½"	5°43'29"	24.702	119.702	173.702	9.975	7°04'19"	27.000	74'-6"	1°58'43"	8 1/16"	120.302	10.025	10	74.345
12	18	8'-0"	10'-0"	24'-0"	6½"	4°46'19"	29.750	143.748	227.750	11.978	5°14'10"	42.001	99'-0"	1°14'15"	13"	144.248	12.021	12	99.470
12	18	8'-0"	10'-0"	16'-6"	6½"	4°46'19"	29.750	143.748	201.750	11.978	4°49'16"	29.001	86'-0"	1°47'56"	9"	144.248	12.021	12	86.190
15	20	8'-0"	12'-0"	24'-0"	6½"	3°49'06"	37.301	179.799	267.301	14.983	3°06'09"	43.751	115'-0"	1°14'15"	13"	180.199	15.017	15	115.240
15	20	8'-0"	12'-0"	16'-6"	6½"	3°49'06"	37.301	179.799	235.301	14.983	2°41'36"	27.751	99'-0"	1°47'56"	9"	180.199	15.017	15	99.400
16	20	8'-0"	12'-0"	24'-0"	6½"	3°34'47"	39.815	191.817	279.815	15.985	2°39'26"	43.998	120'-0"	1°14'15"	13"	192.193	16.016	16	120.208
20	27	9'-6"	17'-6"	30'-0"	6½"	2°51'51"	49.806	239.642	348.806	19.970	1°41'17"	54.582	149'-6"	0°59'23"	16½"	240.152	20.013	20	150.464

Fig. 219.—Turnouts and Crossovers; Baltimore & Ohio Ry.

with a flangeway of 1¾ ins.; each end is flared to give a flangeway of 2½ ins. at 18 ins. from the straight portion. In turnouts of the Lehigh Valley Ry., the spread of the switch at the heel is uniformly 6 ins. The standard table and diagram of the Baltimore & Ohio Ry. are given in Fig. 219, and some notes accompanying this table are given below:

Spring-rail frogs are to be used in main tracks at high-speed points when the turnout is used at comparatively low speeds; also on turnouts for busi-

ness tracks, etc., from passing sidings, and in general where the traffic on one track is much greater than on the other. Hard-faced rigid frogs are to be used at end of double track and similar places when both tracks are subjected to heavy traffic at high speeds. All No. 1ᴊ to No. 20 frogs inclusive shall be of hard-faced construction. Sliding-wing frogs are to be used where the traffic is slow and heavy on both tracks, as on yard ladders and other such places not in main tracks. Rigid Bessemer frogs are to be used for tracks of light traffic, such as storage tracks, industrial tracks connecting with other sidings, etc. Other frogs and frogs of the kinds noted above to take care of special and extraordinary conditions of alinement and traffic may be used on authority of the Engineer of Maintenance-of-Way.

For end of double tracks and crossovers used at high speed, use No. 20 frogs. For passing sidings, use No. 10 frogs, when turnout is not controlled by interlocking, and No. 16 frogs when turnout is controlled by interlocking. For other sidings in main tracks and for general yard work, use No. 8 frogs.

Wharton switches shall be used in the main tracks at high-speed points at facing-point turnouts leading from the outside of a curve connecting to industrial sidings or other sidings not frequently used. They shall never be used at turnouts leading from the low side of a curve. They shall not be used at the ends of passing sidings except where special conditions make it advisable to use them.

Split switches shall be used at all other points. With No. 20 frogs, use 30-ft. switches. With No. 12 to No. 16 frogs, use 24-ft. switches. With No. 7 to No. 12 frogs in main track, and with No. 10 frogs in sidetracks, use 16½-ft. switches. With sidetrack frogs No. 6 to No. 10 and No. 6 main-track frogs, use 13-ft. switches. When possible use 13-ft. repaired switches for sidetrack frogs No. 6 to No. 10. With frogs below No. 6, use 11-ft. switches; when possible use 11-ft. repaired switches for sidetrack frogs under No. 6.

TABLE NO. 38.—TURNOUTS (100-LB. RAILS); NEW YORK, NEW HAVEN & HARTFORD RY.

Frog number	8	10	10	15
Style of frog	Rigid.	Rigid.	Spring.	Rigid.
Angle of frog (A)	7° 10′	5° 43′ 54″	5° 43′ 54″	3° 49′ 12″
Lead (B) (calculated)	66 ft. 3 ins.	76 ft. 1 in.	74 ft. 1¼ ins.	111 ft. 7⅜ ins.
" (C) (calculated)	47 " 11 "	56 " 11 ins.	51 " 1¼ "	81 " 4⅜ "
" (B) (actual)	66 " 8 "	75 " 7 "	75 " 7¼ "	112 " 10½ "
" (C) (actual)	48 " 0 "	56 " 0 "	52 " 0 "	82 " 0 "
Rails for lead (C); (No. and length)	(2) 24	(2) 28 or (1) 30, (1) 26	(2) 26 or (1) 28, (1) 24	(1) 30, (1) 28 and (1) 24
Radius of lead (C), ft.	517.98	843.36	757.26	1,973.93
Length of switch rail (D), ft.	15	15	15	24
Throw of switch rail, ins.	3⅜	3⅜	3⅜	3⅜
Switch angle (E)	1° 52′	1° 52′	1° 52′	1° 10′
Spread of switch (F), ins.	6¼	6¼	6¼	3 11/16 at 14 ft. 6 5/16 at 24 ft.

Crossovers.—A crossover is a diagonal track connecting two parallel tracks, and consists of two turnouts connected by a short tangent, although where space is limited and the crossover is to be used only at slow speeds it may have the turnout curves united as reversed curves. On double track the crossover should be laid out with trailing switches, being used only by backward movements. The length of the crossover will depend upon the frog number and the distance between tracks. In Fig. 216 (diagram 212): A = distance between frog points (measured along the main track), B = distance between gage sides of inner rails of the two tracks, C = gage of track, D = frog number. Then: $A = (B - C) \times D$. The rule of the Hocking Valley Ry. has been given above. For a turnout with frogs of different numbers, D and D'; first find the distance A for both D and D' by the above formula. Then half the sum of these two distances will give the distance A for the required combination. For the diagonal distance DD between frog points, add the squares

of A and B, and take the square root. The table in Fig. 219 gives the distances between frog points and switch points.

Ladder Tracks.—These are diagonal tracks from which a series of parallel body tracks diverge. The angle between the ladder and body tracks conforms to that of the first frog, and all the frogs should be of the same number. Putting in a ladder track at an angle with the body tracks greater than that of the frog angle will necessitate varying the distance c. to c. of tracks, and requires special formulas for calculating this distance. For ordinary work, the same frogs should be used throughout and the body tracks should be lined in with a transit. Another method is to obtain from a table the perpendicular distance from the gage side of the main-track rail to the ladder rail at certain distances along the former. This of course will vary with the frog number, and will give points in the ladder rail. The distance between the frog points is calculated by dividing the distance c. to c. of tracks by the sine of the frog angle. This distance should be measured along the ladder rail, making allowance for the actual or blunt point in the first frog, and then measuring the distances, which will give the positions of the actual points. Stakes may then be set for the points of frogs and switches, using the theoretical leads. The frog point is placed opposite its stake and the point of switch allowed to fall where the shortened lead brings it. A string stretched across the ladder rail, parallel with the main rail at a distance equal to the specified distance c. to c. of tracks, will also mark the position of the frog. Stakes should be set to give the line of one of the body tracks, the others being put in by measurements made by the foreman. ("Engineering News," March 28, 1901.)

Ladder tracks should be laid out to the greatest possible angle for the frog used, and the following method was used by Mr. C. S. Sims on the Pennsylvania Lines: Take the minimum length of lead for the frog to be used for the yard, which is the distance from the point of frog to the point of switch. Add to this the amount of clearance from the point of frog back to the point of the next switch. With a No. 7 frog the lead is 60 ft.; the clearance distance will be 10 ft., making 70 ft. in all from switch to switch. If the body tracks in the yard are to be laid out 12 ft. c. to c., dividing 12 by 70 will give the natural sine of the ladder angle, A, as shown in Fig. 220. If the body tracks are 13 ft. apart, substitute 13 for 12. One of the advantages of this method is that it puts a little curve behind the frog. This corrects all inaccuracies in laying out the track and makes the ladder look straight and perfect, and all the body tracks swing off from it similarly, while if the exact frog angle is used for the ladder the slightest error in location is evident. Care should be taken in staking out ladder tracks to first determine the ladder angle, and then to turn it carefully with the transit from the track from which the ladder opens, and put in a line of stakes. On this line the switches should then be located the exact distance apart as called for by the original assumption. The switches will then be the least possible distance apart, which is an advantage. The angle of the ladder will be the greatest possible, which gives the maximum car capacity of the yard for the amount of space occupied. Fig. 220 shows also the arrangement of the Chicago, Rock Island & Pacific Ry. for a ladder track with No. 10 frog in main track and No. 8 frogs for the body tracks. The ladder track should not open from a main running track (especially where interlocking plants are used), but preferably from a siding or lead track whose main-track connection is at least 500 ft. in advance of the ladder-track connection.

While No. 9 frogs are recommended for yard ladders, many railways use No. 8 or even No. 7. These latter put the switches closer together and thus give a shorter distance for the cars to travel in switching. This is of importance in utilizing the space and in operating the yard. However, No. 7 should be the minimum for yards of modern design.

On the Michigan Central Ry., the practice is to use a No. 11 frog in the main track for all yard leads whenever practicable. The angle of ladder track is 9° 1′; the frogs are No. 9, and the tracks 13 ft. c. to c. The distance between switches is 83 ft., as follows: Lead, 72.43 ft.; frog length beyond point, 8 ft.; straight track to bend in stock rail, 1.95 ft.; bend to switch point, 0.68 ft. In staking out the work, the point of intersection of the center lines of main and ladder tracks is first decided upon; the No. 11 frog is then located, and

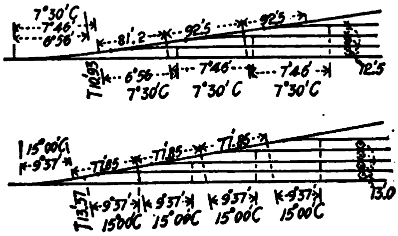
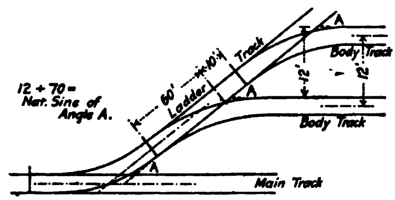
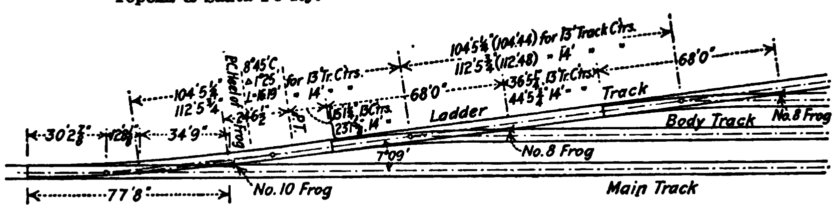


Diagram of Yard Entrances; Atchison, Topeka & Santa Fé Ry.



Ladder-Track Connections; Pennsylvania Lines.



Ladder Track; Chicago, Rock Island & Pacific Ry.
(No. 10 frog in main track; No. 8 frogs in ladder track.)

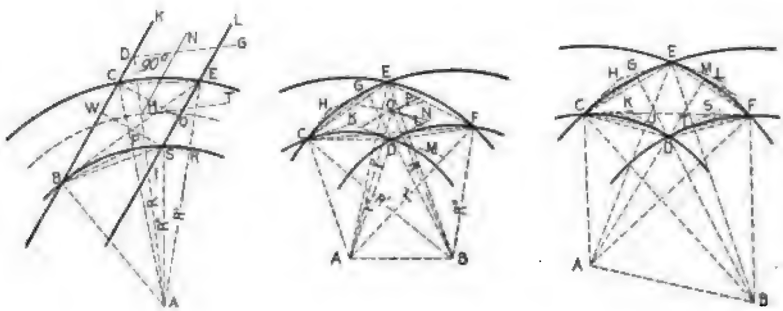
Fig. 220.—Plans of Ladder Tracks.

the P.C. and P.T. of the turnout curve. The transit is set over the point of intersection, the angle of the ladder track turned off, and stakes set along the center line for the headblock, point of frog and point of curve, according to the standard plan. The transit is then placed on the center line of the first body track, opposite the frog point, the angle of ladder is turned, and stakes are set for the frog points of the other tracks (83 ft. apart). It is then set on the center line of the track at the point of curve, the angle again turned, and stakes set for P.C. of each track. Finally it is set on the center line of the point of tangent, the angle again turned, and stakes set (83 ft. apart) for P.T. of each track. The foreman then lays out the switches according to standard offset measurements.

Crossings.—The calculations for crossing frogs at track intersections are apt to be somewhat complicated. The crossings should always be put in under the direction of an engineer, stakes being set to mark the center lines of the two tracks. Any lining at crossings should always be done with reference to the engineer's stakes. In the renewal of crossings, the angles should first

be carefully measured, and the lines set out by instruments. It will very generally be found that the alinement has been affected by creeping of the rails, unless these have been anchored or secured by check plates. The gage of tracks should also be measured. If the alinement is bad, the proper location should be made before the frogs are ordered. If the two tracks belong to different roads, this matter should be arranged before any work is done. If the two tracks have rails of different weights, the crossing should be built of the heavier rails, and a length or two of this rail laid beyond the frogs on the lighter track, so as to avoid excessive shock at the crossing. Particulars in regard to crossings will be found in Chapters 7 and 9.

Crossings of curved tracks involve special difficulties. The degree of curve should be verified by measuring the tangent offset, and by taking supplementary angles checked by measurements with a chain or steel tape. It is impossible to make a satisfactory plan of a curved crossing by taking measurements of the diagonal and of ordinates to the curve. The proper way is to run out the curve and get the angle of intersection, calculate the angles and distances and check these from a large scale drawing. The angle of crossing will be equal to the angle between the radii to the common point. The practice on the



Case 1. Case 2. Case 3.

Fig. 221.—Track Crossings at Grade on Curves.

Michigan Central Ry. is to take the angle of a crossing frog in the track with a transit, and then confirm the observed angle by tape measurements. The point is found at which the gage lines of the frog meet, and then a mark is made on the gage side of each rail forming the frog at a distance of 3 ft. from the intersection of the gage lines, measured toward the heel of the frog. The distance between these marks is measured and divided by 6, which gives the sine of half the angle of the frog. This angle is of course the angle of the crossing if both tracks are straight lines. If the crossing is formed by one straight and one curved track, or by two curved tracks, the intersection of gage lines at each of the four corners of the diamond is found, also the angle of each frog in the manner stated above. All the connecting distances between the intersections of gage lines are measured, to confirm the calculations, which are anything but simple. As this is a detail of track work not generally explained outside of railway offices, some particulars are given below, and further discussion will be found in "Engineering News," April 21, June 16, July 23, and Sept. 29, 1898. The diagrams in Fig. 221 and the following calculations represent the practice on the Michigan Central Ry.

Case 1.—Crossing of Curved Track and Straight Track.—Calculation of the Frog Angles and Chord Lengths:

Observe the central angle $\overline{NHT}$.
D, R = radius central curve.
$R' = R + \frac{1}{2}$ gage.
$R'' = R - \frac{1}{2}$ gage.
Let F, F', F'', F''' = frog angles at S, B, C, and E.

$\overline{NHT} = \overline{KDG}$. $DH = HI = \frac{\frac{1}{2}\text{ gage}}{\cos \overline{KDG}}$. $AD = R + DH$. $AI = R - HI$.

$\overline{CDA} = 90° - \overline{KDG}$. $\overline{EIA} = 180° - \overline{CDA}$.

$\sin \overline{KCA} : AD = \sin \overline{CDA} : R'$ $\therefore \sin \overline{KCA} = \frac{AD \times \sin \overline{CDA}}{R'}$.

$\sin \overline{KBA} : AD = \sin \overline{CDA} : R''$ $\therefore \sin KBA = \frac{AD \times \sin \overline{CDA}}{R''}$.

$\sin \overline{IEA} : AI = \sin \overline{EIA} = R'$ $\therefore \sin \overline{IEA} = \frac{AI \times \sin \overline{EIA}}{R'}$.

$\sin \overline{ISA} : AI = \sin \overline{EIA} = R''$ $\therefore \sin \overline{ISA} = \frac{AI \times \sin EIA}{R''}$.

$90° - \overline{ISA} = F$. $90° - \overline{IEA} = F'''$. $\overline{KBA} - 90° = F'$. $\overline{KCA} - 90° = F''$.

To find chord lengths: $\overline{WBS} = F' + \frac{1}{2}(F - F')$. $\overline{OEC} = F''' - \frac{1}{2}(F''' - F'')$.

$\overline{CBP} = F' + \frac{1}{2}(F'' - F')$. $\overline{BPC} = 90° + \frac{1}{2}(F'' - F')$.

$\overline{ESR} = F + \frac{1}{2}(F''' - F)$. $\overline{SRE} = 90° + \frac{1}{2}(F''' - F)$.

$BS = \frac{\text{gage}}{\sin \overline{WBS}}$. $CE = \frac{\text{gage}}{\sin \overline{OEC}}$.

$\sin \overline{CBP} : \text{gage} = \sin \overline{BPC} : BC$ $\therefore BC = \frac{\sin \overline{BPC} \times g}{\sin CBP}$.

$\sin \overline{ESR} : \text{gage} = \sin \overline{SRE} : SE$ $\therefore SE = \frac{\sin \overline{SRE} \times g}{\sin ESR}$.

To check, compute side BE from the triangle BSE and CBE.

Case 2.—Crossing of Two Curved Tracks.—Calculation for the Frog Angles and Chord Lengths:

Observe the central angle $\overline{NOP}$, or any frog angle, as $\overline{HCK}$.
AB = Distance between the centers of the two curves
R = Longer radius of center line.
r = Shorter radius of center line.
$R' = R + \frac{1}{2}g$, $R'' = R - \frac{1}{2}g$, $r' = r + \frac{1}{2}g$, $r'' = r - \frac{1}{2}g$.

1. If central angle is known, $\overline{AOB} = \overline{NOP}$. In triangle AOB

$$\tan \overline{ABO} = \frac{r \cdot \sin \overline{AOB}}{R - r \cos \overline{AOB}}, \text{ and side } AB = \frac{r \cdot \sin \overline{AOB}}{\sin \overline{ABO}}.$$

2. If a frog angle is observed, as $\overline{HCK}$, find AB in like manner from triangle ABC.

3. All the sides of the triangles ACB, AEB, AFB, and ADB, being known, compute all the angles of each triangle. The angles at C, E, D, and F, thus found, will be the frog angles required.

4. To find the chord length CD, produce BD to G; $\overline{KCD} = \frac{1}{2}\overline{CAD} = \frac{1}{2}(\overline{CAB} - \overline{DAB})$, $\overline{HCG} = \frac{1}{2}\overline{CBG} = \frac{1}{2}(\overline{ABD} - \overline{ABC})$; $\overline{GCD} = \overline{HCK} \pm \overline{KCD} \pm \overline{HCG}$, $CGD = 90° \pm \overline{HGC}$, GD = gage.

$\therefore$ From triangle CGD, $CD = \frac{\sin \overline{CGD} \cdot g}{\sin \overline{GCD}}$. In the same way find chords CE, EF and FD.

5. Compute value of CF from triangles ECF and DCF to check the work.

Case 3.—Crossing of Two Curved Tracks.—Calculation for the Chord Lengths when the Frog Angles are all known:

$\overline{KCD} = \frac{1}{2}(\overline{CAB} - \overline{DAB})$,

$\overline{HCG} = \frac{1}{2}(\overline{ABD} - \overline{ABC})$,

$\overline{GCD} = \overline{HCK} \pm \overline{KCD} \pm \overline{HCG}$,

$\overline{CGD} = 90° \pm \overline{HGC}$,

$GD = \text{gage}$; $CD = \frac{g \cdot \sin \overline{CGD}}{\sin \overline{GCD}}$.

$\overline{SFD} = \frac{1}{2}(\overline{ABF} - \overline{ABD})$,

$\overline{LFM} = \frac{1}{2}(\overline{DAB} - \overline{FAB})$,

$\overline{MFD} = \overline{LFS} \pm \overline{LFM} \pm \overline{SFD}$,

$\overline{FMD} = 90° \pm \overline{LFM}$,

$DM = \text{gage}$; $DF = \frac{g \cdot \sin \overline{FMO}}{\sin \overline{MFD}}$.

$$\overline{LFE} = \tfrac{1}{2}(\overline{EAB} - \overline{FAB}), \qquad \overline{HCE} = \tfrac{1}{2}(\overline{ABE} - \overline{ABC}),$$
$$\overline{SFT} = \tfrac{1}{2}(\overline{FBA} - \overline{EBA}), \qquad \overline{KCJ} = \tfrac{1}{2}(\overline{CAB} - \overline{EAB}),$$
$$\overline{EFT} = \overline{LFT} \pm \overline{LFE} \pm \overline{SFT}, \qquad \overline{JCE} = \overline{HCK} \pm \overline{KCJ} \pm \overline{HCE},$$
$$\overline{ETF} = 90° \pm \overline{SFT}, \qquad \overline{CJE} = 90° \pm \overline{KCJ},$$
$$ET = \text{gage}; \quad EF = \frac{g \cdot \sin \overline{ETF}}{\sin \overline{EFT}}. \qquad EJ = \text{gage}; \quad CE = \frac{g \cdot \sin \overline{CJE}}{\sin \overline{JCE}}.$$

Moving Switches by Locomotives.—It is sometimes necessary to move a system of switches, or a ladder in a yard, to accommodate improvements. If the distance is not too long, an engine with a wrecking rope can pull one turnout at a time readily. Remove the track intervening between the old and new locations, excavate the ballast to the bottom of the ties, cut the track between the turnouts, and put 1-in. boards under the ends of the switch timbers, lapping them in the direction the switch is to be pulled. Fasten each end of a chain around the rails and sill on each side of the switch, preferably behind a joint, and hook the engine rope to the middle of this chain, so as to prevent the strain from being greater on one side, and thus twisting the switch timbers. When the turnout is in its required position, put in the connecting rails and splice up the track. The engine pulls the turnouts consecutively. A ladder has been changed in this manner in one day, which could not have been done by hand with the same force of men in ten days.

Switch Repair Work.—A considerable amount of switch and frog repair work is done at the blacksmith shops of many railways. The maintenance-of-way department of the Missouri Pacific Ry. has a traveling blacksmith outfit, which is found very economical in frog repairs. There are two cars: one is for stores and has accommodation for the blacksmith and his helper; the other is a flat car with forge, rail bender, and other tools. The cars are moved in local trains. When a frog is removed, a piece of rail is spiked in place temporarily for the main track. This outfit avoids the delay and expense of shipping heavy frogs to and from the division shops. The blacksmith also sharpens track tools, repairs hand cars and does other necessary work.

Instructions for Switch Work.—The following are the instructions issued by the maintenance-of-way department of the Baltimore & Ohio Ry. for putting in turnouts, and for the maintenance of switches, frogs and turnouts:

Putting in Turnouts.—(1) Locate the frog and switch points, and put in the ties, care being taken to have them square with the main track. (2) Put slide plates and braces under the unbroken side of main track, placing shims of the proper thickness on the opposite side of ties. (3) Line and full spike the unbroken side on new ties and spike the guard rail to proper position. (4) Couple up frog and main-track lead rails, and main-track switch points on the new ties on the turnout side, doing such cutting and drilling as may be required to complete the main-track lead to the proper length from the point of the switch to the heel of the frog. (5) Break the main track at the position of the heel of the frog and throw the main-track rails for the siding, bending the stock rail at the same time. This can be done without taking the stock rail out of the track. Throw in the main-track lead, which has already been coupled, bolt the main-track end of the frog, and then spike the new section to the proper gage from the frog to the switch, putting on the proper slides and braces. (6) Couple up the switch point for the siding by rods, making such adjustments in the rods as are necessary. Cut the rails to complete the siding turnout from the heel of the switch to the point of the frog, and spike the siding lead to the proper line for the turnout curves. (7) Complete the work of laying the turnout by the necessary spiking, gaging and adjustment of switchstand, and see that the angle bars in the main track each way from

the turnout are fully spiked in the slot holes to prevent creeping of the main-track rails. The two switch points must be exactly opposite each other, and to aid in obtaining that result, the following excess length of sidetrack lead rail over main-track lead rail is given for straight main track: For No. 4 frog, 4½ ins.; No. 5, 3½ ins.; No. 6, 3 ins.; No. 7, 2½ ins.; No. 8, 2 ins.; No. 10, 1¾ ins.; No. 20, 1¼ ins.

In setting semaphore switchstands, the blade shall, in all cases, point towards the engineman's right as he approaches a facing-switch point, even though the stand is (for some reason) on the fireman's side of the track. High semaphore stands shall be placed 7 ft. from the near rail when on the engineman's side of the track, and 8 ft. when on the fireman's side of track. Where the white banner of switch targets is inclined, it shall always slope downward towards the engineman's right when approaching a facing-point switch.

Care of Frogs and Switches.—Spring-rail frogs, sliding frogs, movable-point frogs and split switches shall be kept well cleaned and oiled at all times. Bolts shall be kept tight in frogs, switches, crossing frogs and slip switches; and cotters shall be kept in place where provided for. Bolts fastening switch rods to lugs shall be placed with heads up and provided with cotters. Particular attention is called to the need of maintaining good line and surface at all times through turnouts, etc. If the ties at or near the joint fastening become lower than those adjoining them, the bent portion of the spring rail of spring-rail frogs, or the points of movable-point frogs and split switches, will rise as the wheels pass over the joint, causing great danger to traffic.

Care should be exercised to see that the gage is maintained true at split switches and at movable-point frogs, and that all frogs, switches, etc., are kept free from snow, ice and other obstructions. The points shall fit snugly in either position at all times. The standard guard rail shall be used to protect all frog points, and all guard rails shall be frequently inspected to see that they are secure and set to proper gage. Their proper position opposite the point of frog is not less than 4 ft. 6¾ ins. from the gage line of frog point, nor more than 4 ft. 5 ins. from gage line of frog wing rail. The connections between main rails and frogs and switches shall be made with standard angle bars, wherever practicable. Switchstands must be kept firmly spiked to the head ties, standing plumb, with the targets square with the track. Switch signals must be kept bright and in good order; they shall be painted as often as is necessary to preserve proper appearance.

The bend in the stock rail shall be at such distance ahead of the switch point as will make the gage line continuous, and the stock rail shall be bent the proper amount. When the turnout is used for main traffic, a guard rail shall be placed ahead of the switch point on the turnout side to decrease the wear of the opposite point. Any unusual wear of switch points should be carefully investigated to learn the cause and apply the remedy. The use of new material in sidings should be avoided as far as possible. Supervisors must regularly inspect all frogs and switches to see that they are properly maintained.

CHAPTER 25.—BRIDGE WORK AND TELEGRAPH WORK.

Bridge Work.

The maintenance, repair and renewal of bridges and trestles on large railways is usually in charge of a separate department, as noted in Chapter 17, but it is a matter with which the maintenance-of-way department is intimately connected. The general system of organization is to have working gangs under master carpenters or bridge foremen who report to a general foreman or supervisor. This last officer may report to the division engineer, the engineer of maintenance-of-way, or the superintendent (or engineer) of bridges and buildings. Many railways consider it best and most economical to do bridge

renewal work by company forces rather than by contract. In some cases all foundation work, masonry substructure and superstructure work, and the erection of steel superstructures, is also done by company forces. This is the practice on the Chicago, Milwaukee & St. Paul Ry. The Atchison, Topeka & Santa Fé Ry. also does steel erection by its own permanent bridge erecting gangs. This arrangement calls for careful organization and complete equipment. The bridge gangs should have permanent work trains, including boarding and sleeping accommodation, so that the men can live comfortably. With such an arrangement, the bridge department can secure and keep better men than would otherwise be the case. The renewal or reconstruction of old bridges is usually a difficult matter, on account of the necessity of avoiding interference with traffic, and of keeping the structure in safe condition at all times. In the construction of a double-track viaduct to take the place of a single-track viaduct on the Cincinnati Southern Ry., the working time was only 3 to 6 hours of each 8-hour day. Traffic was operated by the train-staff system, a temporary signal tower being erected and the work train holding one staff when at work. The telegraph operator at the tower notified this train when to clear the track. The switch to the sidetrack could not be closed and locked without the staff, and the signal could not be lowered until this had been done and the staff inserted in the machine at the tower. This work was done by contract, and was described in "Engineering News," June 8, 1905. In bridge repair or renewals on double track the tracks may be gantletted along the middle of the structure, thus giving more room for work. To prevent accidents, fixed danger signals may be placed at each end of the gantlet, and no train allowed to pass unless the pilotman assigned to that duty is on the engine.

Derrick cars are of great importance for handling material in bridge work, and various designs were described in the Proceedings of the Association of Superintendents of Bridges and Buildings in 1902. Wrecking cranes (described elsewhere) are employed in work of this kind (see also Figs. 226 and 230). A machine of this kind can unload material and place it in position in advance, so that for short spans and for viaduct work no falsework may be necessary. Where falsework is used, two cars (or two wrecking cranes) can handle the girders, one at each end. On the Cincinnati Southern Ry. viaduct, noted above, two steam derricks were used, with 40-ft. booms and 20 tons hoisting capacity. These unloaded the girders, columns, etc., from the cars and set them in position; the columns were set by lowering the foot from one derrick while the upper end was suspended from the other. The heaviest pieces were 17-ton columns, and 20-ton 75-ft. girders. The Chicago, Milwaukee & St. Paul Ry. has a steel derrick car with a box-lattice boom made in two sections, put together at the splice with turned bolts. The sections are 15 and 21 ft. long, and the length of the boom can be made 42 to 80 ft., with a hoisting capacity of 50 and 10 tons respectively. This machine can place the parts of viaducts 75 ft. in advance, and can set a 95-ft. girder without the use of falsework. The car has a plate-girder frame 50 ft. long, on trucks 40 ft. apart. At the front end is a 20-ft. A-frame, with eyebars in the backstay; by removing one pin, the eyebars can be lowered, and the A-frame swung back to lie on the floor for transportation. At the rear end are the boiler, 50-HP. engine, and air pump supplying compressed air for the riveting hammers. The machine is self-propelling. Lighter cars on the same road can handle 30 and 20 tons at the ends

of 30-ft. and 50-ft. booms. They can set a 70-ft. girder in place without falsework, or an 80-ft. girder when working from falsework. An air-compressor outfit may be placed in the derrick car or in the tool car, to operate pneumatic riveters, drills, sand-blast jets, etc. A bridge-gang tool car on the Lehigh Valley Ry. has a 25-HP. gasoline engine, 10×10-in. air compressor, 12-KW. dynamo (225-volt current), air receiver, cooling tanks, pneumatic tools, two forges, a cold saw, and 100 portable lamps of 16 c.p., with wires.

In renewing an old plate-girder bridge, falsework is sometimes built under it and extending on both sides. The new span is erected on this, beside the old one. The latter is then pulled sideways till clear of the masonry, and the new one pulled into its position. The pulling is done by tackle led to locomotives. The bridges usually slide on rails laid upon the falsework. In using this method for a number of 80-ft. bridges in the double-tracking of the Union Pacific Ry., each corner of the new bridge had a 7½-in. grooved steel wheel or roller resting on a rail on the falsework. This facilitated the movement. A bridge could be renewed in about an hour, from the time of cutting the track to reconnecting it ready for traffic.

For timber repair work, it is usually best to have one main yard for timber and piles, and to keep only an emergency stock on each division. Timber that is removed is not necessarily useless, but may be made available in other repair work, and should be piled for examination as to its availability and value. In making renewals with creosoted timber, all parts cut for framing, etc., must be saturated with creosote oil by repeated applications, and then well daubed with hot pitch, this being done as soon as the stick is cut. Every gang using such timber should have a supply of oil and pitch and a 10-gallon pot for heating it. A useful tool for a bridge gang in handling timber is a truck, or "dolly," having a grooved wheel 6 ins. diameter and 3½-ins. wide (7½-ins. and 4¾-ins. over the flanges) journaled in bearings attached to two side timbers 2½×6 ins., 18 ins. long. A curved handle is fitted on one side. A larger dolly may have two wheels (placed tandem) with side timbers 3 ft. long.

Rules for painting steel bridges were given by Mr. W. G. Berg in "Engineering News," June 6, 1895. Railways should, as far as possible, undertake the purchase of the raw supplies and the mixing of the paint (by hand or machine), thus being able to insure that the best pigments and oil are used. Painting in the field should be done by the railway, and not by contract. For new work, the priming coat may be of pure, finely ground, dry red lead, toned down with lampblack, and mixed with pure, raw linseed oil, adding as little drier as possible. The finishing coats may be of any suitable paint, preferably dark-colored, providing the quality of the pigment is not injurious and the linseed oil is pure. If a cheap paint is required, use oxide-of-iron paint, bought in powder form and toned down with lampblack, in preference to cheap ready-mixed paints. Paint should not be applied when the metal is wet or the weather cold. The Northern Pacific Ry. uses the following: 1st coat, 30 lbs. pure lead to 1 gallon pure boiled linseed oil and ⅓-pint pure turpentine; 2d coat, 25 lbs. lead, 1 gallon oil, ¼-pint turpentine and not over 12 ounces of lampblack; 3d coat, 15 lbs. dry pigment to 1 gallon of oil. The quantity has been estimated at ⅝-gallon of paint per ton for the first coat, and ¾-gallon for the second coat. For repainting old work, first remove all dirt, grease, rust, scale and soft paint. If the work is in bad condition, use a red-lead primer coat, followed by finishing coats as abtove. If it is in fair condition,

touch up the bare spots with a preliminary extra coat, and then apply the finishing coat. Where bridge contracts include erection they frequently call for one coat of paint after erection, but the work is frequently unsatisfactory to the railway paint department, both as to material and workmanship. An accumulation of damp cinders and dirt at rail seats, etc., will cause disintegration of paint and corrosion of the metal.

Detailed descriptions of all bridges are usually kept at headquarters. These show for each individual structure the type, dimensions, waterway, substructure and superstructure, date of construction and renewal, and the dates of inspections (with references to the books in which the inspections are recorded). Similar records are kept at the division offices, and (condensed) in pocketbook form by the engineers or inspectors. (American Railway Engineering Association, 1904.) These records are discussed later under "Records."

The classification of bridges as to their strength or carrying capacity is a very important matter on many railways, where heavy train loads and axle loads are imposed upon structures of varying age and quality. This is important not only in regard to railway bridges, but also in regard to existing highway bridges which are to be utilized by new electric railways or where heavy interurban cars are supplementing lighter cars. This matter is treated in a paper in the Transactions of the American Society of Civil Engineers for December, 1906, and in the 1908 Proceedings of the American Railway Engineering Association. In a system used by Mr. C. D. Purdon on the St. Louis & San Francisco Ry., each bridge is calculated for a certain loading, and its weakest part is determined. The loading for which it is safe is then ascertained, and the bridge classified according to this latter.

Bridge Inspection.

All bridges, viaducts and trestles of steel and timber must be inspected periodically for two different purposes: (1) For general maintenance; to see that they are in proper condition as to painting, end bearings, expansion joints, floor system, and general condition. (2) For renewal; to ascertain the condition as to safety and durability, and to determine the amount of renewal work or the necessity for replacement. Annual inspections may suffice where the bridges are modern and of ample capacity for the loads. Old structures must be watched and inspected frequently by the section foremen or men in direct charge, who are not relieved of any responsibility by the official inspections. Special inspections and reports must also be made upon every piece of renewal or reconstruction as soon as it is completed. An annual inspection is usually made by the higher officials to check the reports of division officers, and to determine upon the renewal work for the next year.

The system of inspection recommended by the American Railway Engineering Association in 1908 is as follows, and the practice of several railways was reviewed in its Proceedings for 1907: (1) Daily by trackmen, who look out for damage by drift or high water, broken or damaged ties and other evident defects. They only report in case something wrong is discovered. (2) Monthly by bridge men, who examine every member and part of both superstructure and substructure. They look out for cracks, wear, loose members, loose rivets, deterioration of the masonry, scouring or undermining of foundation. They also observe the action of the structure under traffic, with the object of detecting any new, unusual or excessive motion. (3) Quarterly

by bridge men, who inspect in detail certain specified structures. The bridge men make reports of both monthly and quarterly inspections. (4) Annually by a bridge inspector, to check the monthly and quarterly inspections; he reports on the extent of defects, deterioration, motion, etc. From this may be determined the degree of safety, the necessity for repairs and the extent of strengthening and renewals required. (5) Annually, by the authorities in charge of bridges, for the purpose of officially deciding the extent of reinforcing, renewals or traffic restrictions which must be made during the following year. (6) Special inspections: A, Structures which are severely strained or show signs of distress under traffic; B, Substructures which show signs of movement, until the movement ceases, or the conditions causing it have been remedied; C, After heavy freshets for evidence of damage to superstructures by drift and to substructures by scour; D, By the engineering department when a structure is reported as requiring extensive repairs or renewal.

The inspector should be familiar with bridge design and stresses, and also have practical experience in shop work, field work, timber framing, etc. He should be furnished with a list of the bridges to be inspected, the list indicating which require special watching and which may be inspected quarterly. The reports are usually made on printed forms bound in a book of pocket size. Sometimes the record is made in duplicate, the inspector keeping one copy. Instructions governing the inspector's duties should be printed in each book. The inspector's record should be so clear and complete that the bridge foreman has full details and can arrange to finish up all work at one place at a time. This avoids waste of time in traveling, but, of course, any emergency work must be attended to first. Most roads issue special instructions as to bridge inspection, and have blank forms for reports and records. Every opening, however small, should be given a number for ease of reference and location.

The inspection report may be on a card 5×8 ins., ruled to include trestles and girder and truss bridges; also the condition of piers and paint, and the condition of individual parts of wooden structures. It may include a bill of material and itemized estimate of cost for repairs, and a column for the actual cost. Symbols may show whether the bridge has been repaired or renewed since the last report; and whether it is good for another year, or should be renewed at once or in 6 months. The Illinois Central Ry. uses a sheet 8½×14 ins. for the monthly and quarterly reports of the supervisor of bridges and buildings, a copy being sent quarterly to the roadmaster. The 8½-in. width is divided into 10 columns, and a line is given to each structure; these show date of inspection, bridge number, length, kind of structure, number of bents, number of piles per bent, when built (year and month), condition, work needed in next 3 months. In some cases the reports are made in a book of blank forms of pocket size, a page being taken for each structure. At the top are lines for the bridge number, division, inspector, and date. At the left is a list of parts, with one or more lines to each, and several lines for remarks. They are sometimes in tabular form, with two pages 5½×8 ins. The left-hand page has vertical columns for bridge number (or structure), location, kind of structure, description, date of inspection. The right-hand page is for notes as to general condition, work required, and recommendations. A similar report, but with the pages combined on a sheet 11×8 ins., is used for the office (American Railway Engineering Association, 1904, 1907).

On the Erie Ry., the division engineers report quarterly to the superintendents. The report is on a sheet 28×30 ins., with columns for remarks by the division engineer, division superintendent and engineer of maintenance-of-way, and a column for "action under train." There are also 12 columns for general conditions: 1, masonry; 2, bed plates; 3, rollers and frames; 4, pedestals; 5, main trusses or girders; 6, lateral system; 7, metal floor system; 8, wooden floor system; 9, rivets; 10, hangers; 11, castings; 12, paint. A smaller form is used by the bridge inspector in making his monthly report to his roadmaster or division engineer. The quarterly reports go from the division officers to the engineer of maintenance-of-way, thence to the general superintendent and the chief engineer, who refers them to the bridge engineer. On the larger divisions, there are bridge inspectors constantly on the line, and they make special reports when necessary. On the divisions where the traffic is lighter, the master carpenters make these reports. If a defect develops which the division employees are not well prepared to deal with, they call upon the bridge department for help. This it is well prepared to give, as the Erie Ry. erects all its own bridges, and has several gangs of competent bridge men constantly at work. This possible use to which a well-equipped bridge gang can be put is one of the reasons why it is desirable for a railway company to handle its own metal work. Besides the division inspectors, there are two traveling inspectors constantly going over the line, inspecting bridges. They send in their reports weekly, in letter form, to the engineer of bridges and buildings.

All new bridge work is drawn up by the bridge department, general layout plans and stress sheets being made on standard sheets, 8×13 ins. In special cases further details are furnished. The bridge company then draws the shop details. Every drawing of the company is approved by the bridge department in its pencil form. The mill order is made from it by the bridge company, which then makes tracings at its leisure. The mill inspection is let to an inspecting firm, which receives from the bridge company (direct) copies of all mill orders. The railway company handles its own shop inspection. When the metal commences to arrive at the shops, the tracings have been made and approved, and prints are then placed in the hands of the railway's shop inspectors. Prints are sent to the bridge engineer, and copies furnished the erector. All test reports are checked and filed carefully in the bridge department against their respective bridges. Shipping invoices are filed at once in the department, copies being sent to the field for check and return. All plans relating to the structure (masonry, metal, profiles, etc.) are filed under one cover, which is of tough brown paper and the size of the sliding-shelf drawers. Thus they cannot slip about in the drawers, in which they are laid flat.

On the Atchison, Topeka & Santa Fé Ry., a bridge inspector is appointed by and reports to the general foreman of bridges and buildings on each operating division. He is an experienced bridge carpenter, selected with regard to his fitness for the work. It is his duty to examine all bridges, trestles, culverts, cattleguards, stock yards and buildings, taking the main line first and the branches in the order of their importance. He is supposed to examine all wooden bridges once a month, and metal bridges once in two months. He makes a daily report by mail, and sends in his notebook every week; the general foreman examines and signs it, and passes it to the division engineer to be examined and filed. Besides this, an inspection is made in April by the general foreman. roadmaster, division engineer and bridge inspector; and

another in October by the same officers accompanied by the superintendent. At this time all important repairs and renewals for the coming year are determined upon, and a complete report on this work is made to the general superintendent. The bridge engineer receives reports of any defects in bridges. He makes an examination, followed by recommendations as to modifications in the design of wooden structures. For metal bridges, he makes a personal examination, and arranges for proper repairs, reinforcing or replacing. He goes over as large a portion of the system as possible each year, making special trips with the general foreman. He also goes with the superintendents on their inspections as much as possible. Any weak bridges are always given frequent examinations by him or under his direction.

On the Southern Pacific Ry., the bridge superintendents inspect all truss bridges at least twice a year, reporting in April and October, and specifying all structures of every kind that require renewal within the next six months. Every opening must be inspected quarterly by a foreman, who reports to the bridge superintendent. On the Chicago, Burlington & Quincy Ry., the bridge engineer makes semi-annual inspections of all truss and girder bridges over 22 ft. span. He is accompanied by the division master carpenter and generally by the division superintendent, division engineer and engineer of maintenance-of-way and the engineer of district. He also makes special examinations of bridges reported as requiring renewal which seem to call for a heavy expenditure.

The inspector usually travels on a hand car, and is accompanied by the bridge foreman of the division and four bridge men. The men run the car, assist the inspector, and make any minor repairs or those which require prompt attention. The tools include a brace and bits; two or three ¾-in. or ½-in. crank augers, 4½ ft. long, for boring timbers; and two ¾-in. octagon steel bars 4 to 5 ft. long, for sounding timbers. One bar has a bell head 3½-ins. diameter for sounding timbers and piles, and the other end is diamond-pointed. The other bar has one end like a pinch bar and the other either diamond-pointed or flattened to make a scraper for removing sap rot, etc. (See "Tools," Fig. 158.) The diamond point is used for sounding rotten portions. In sounding with the ball head, solid timber will give a firm ring, while rotten wood will give a muffled sound. In boring timber to ascertain its condition, the holes should always be bored from the bottom of the timber, or in an upward inclined direction, so that water will not lodge in them. For iron work, there are required light hammers for testing rivets and light cold chisels for removing rust scale. In testing rivets, the rivet head should be struck a smart light blow sideways, the inspector holding his fingers on the same head and plate at the opposite side from which the blow is struck. Loose rivets should be marked with paint at once. The bridge inspector's hammer used on the New York Central Ry. has a head 4⅝-ins. long; one end is flat, ⅞-in. diameter, and the other ends in a sharp point 5/16-in. long, tapering from ½-in. There should be a 50-ft. tape, 2-ft. rule, plumb-bob and line, monkey wrench, small broom for cleaning dirt from corners, etc. Also paint pots, brushes and stencils for renewing bridge numbers, unless this work is done at other times by the bridge gangs. The inspector should watch every large structure during the passage of a fast train, noting any undue deflection, swaying or vibration, or any significant movement or sound. It may be necessary at times to test the deflection under load. The track should be in good line and surface on the bridge

and approaches, and well bedded on the latter, so as to avoid heavy shocks from trains running onto the bridge at high speed.

Trestles have an average life of 7 to 10 years, the piles being the first part to decay in pile trestles. Where there are many trestles, and especially in damp and marshy country, constant inspection and frequent repair must be made to keep the road in safe condition. There should be also annual or semi-annual inspections in which are noted the alinement and level (or settlement), the vertical positions of bents, conditions of all piles (especially at the water line), timbers, foundations, joints, tenons, braces, corbels, etc., especially where they cross or are framed. The timbers may be bored when necessary to ascertain their condition. A written report may then be made as to each bridge, accompanied by a record of the principal members, special marks indicating whether they will require renewal in 3, 6, 9 or 12 months, or are safe for more than a year. On large trestles the bents may be numbered. Mudsills are sometimes laid in open trenches, sheathed with planking. If buried, the mudsills and feet of posts should have the earth cleared away for a depth of 18 to 20 ins., so that they may be inspected for dry rot. Sap rot should be scraped away to see how much good timber is left. The sway bracing should be well bolted or spiked. The floor system should be examined as to its condition and to see if the stringers have full bearing on the caps and the caps on the piles. The ends must be well supported on the banks.

In inspecting wooden bridges, it should be seen that the trusses have the proper camber, and are vertical, that the chord bolts are snug, and the lateral rods properly adjusted. Then the truss rods should be adjusted until the counterbraces have a firm bearing on the angle blocks, and all the rods have the same tension. The timbers, seats, and joints should be carefully examined for cracks, splits or rot. Splices in bottom chords (principally in long spans, where they generally occur in every panel) must be examined to note if they are pulling apart, which would indicate a weakness or a defective clamp. The braces and counterbraces should have a square and even bearing upon the angle blocks, and any sliding from their position is evidence that the bridge needs adjustment. Such adjustment should be done only under the supervision of the bridge inspector. The truss rods, etc., should not be left loose, and should not be tightened while a load is on the bridge. Wooden bridges may be whitewashed inside and outside twice a year. The Southern Pacific Ry. requires two inspections a year for all wooden bridges and trestles over three years old.

On steel bridges, the bed plates should be level and clean; the rollers clean and free to move, and their axes at right angles to the line of the bridge. The pedestals should be free from cracks and flaws, and have a uniform bearing upon all the rollers or upon the bed plate at the fixed end. Tension members must be closely examined, also the rods and bottom chords, especially where they are composed of more than one member. All the members in any one panel should have an equal strain, and when one member is slack and the other tight, the case should be reported. The compression members, such as posts and top chords, should be straight, without a bend or bulge, and all the joints should bear closely against each other. The laterals and counter rods should be tested by shaking them, and ought never to be allowed to hang loose. They must not be adjusted with a load upon the bridge, and

must be tightened only enough to get a good bearing. All pins and nuts must be examined for signs of wear or movement. Riveted work should be sounded with a hammer to detect loose rivets; and if they cannot be replaced at once they must be marked, and their number and location reported. Bridges in cities, near salt water, or over railway tracks, should be very carefully inspected for signs of corrosion. Painted work must be examined for indications of rust underneath. No water must be allowed to collect in the interior of any parts; drain holes must be provided and kept open, or the places filled. Places where stringers are riveted or fastened to the floor beams, and which are generally not easy of access for inspection on account of the floor, must be examined. Here the rivets are most likely to get loose, and the webs and flanges of the beams and stringers to fail from shearing or crushing. The lateral systems and sway bracing must also be inspected. All the rods should be tight but not overstrained, as the struts are liable to be crippled if too much power is used in adjusting the tension members.

In all structures, the floor system and its supports must be examined, especially the condition of ties or timbers resting on beams or shelf angles. In addition to the inspection of the superstructures, the masonry of abutments and piers should be examined for signs of settlement or displacement; foundations looked to, and soundings taken to ascertain if there are signs of scour. Pedestal stones should be examined for signs of cracking or crushing, and it should be noted if the masonry requires pointing. It should also be observed if the bridge watchmen and section men keep the bridge seats clean, keep the ballast back from the abutments, keep grass and rubbish cleared away from wooden structures, and keep the approaches firmly bedded.

Telegraph Work.

The telegraph line along a railway is usually built by the telegraph company which operates in that territory.* The maintenance is done by the railway as a rule, but sometimes under the direction of a foreman or lineman of the telegraph company. Such work as rebuilding a pole line or renewing wires is done by a gang of men under the direction of a foreman. Ordinary repairs, such as moving or resetting a few poles for track changes, renewing cross-arms and insulators, or repairing breaks in the wires, may be done by the telegraph lineman, having a certain section of line. He gets assistance from the section men when necessary. The gangs and linemen are paid sometimes by the railway and sometimes by the telegraph company, according to contracts. As a rule the railway furnishes labor, but all work is done in accordance with the telegraph company's rules, and this company furnishes the material. On the Illinois Central Ry. each lineman has a division of about 125 miles of railway, depending upon the number of wires and the facilities for getting over the division. If the line is old, however, this length is too much for one man. In such a case, a gang of 15 to 20 experienced men is sent over the division to put the line in good condition. The railway company does all ordinary repair work, and the telegraph company does the reconstruction when that becomes necessary. The poles are 100 to 176 ft. apart (averaging 132 ft.), and carry both telephone and telegraph wires. They are of white cedar in the north and chestnut in the south, with a diameter of about

* See "Tracklaying"; M., St. P. & S. S. M. Ry.; Chapter 18.

11 ins. at the ground line. The lowest cross-arm is 15 ft. above the ground, or 20 ft. at road crossings. A lightning conductor is placed on every seventh pole. The wires are of No. 6 and No. 8 iron, weighing 573 and 378 lbs. per mile; and No. 9 copper, weighing 210 lbs. per mile. The repair work is done throughout the year.

For extensive reconstruction it is generally best to have a general foreman with a well-organized crew, which can work all through the season. If a small force is organized on each division, the work will be nearly done by the time the men have become experienced. The gang should be sent out early in the spring, when plenty of good men can be obtained. They may be carried in a special work train, with boarding and tool cars. In locating the line, care should be taken to avoid sharp curves and sharp changes of grade where possible, and also to locate it so that snowslides, falls of rock, etc., will not be likely to cause damage. If poles have to be set in frozen ground, an iron jet pipe connected with the engine by hose may be used. Where heavy storms prevail from one direction the line should be built on the leeward or "opposite" side of the track, so that if the poles are blown down they will fall away from instead of upon the track. The danger to trains from telegraph poles falling or being blown down upon the track is especially great with tall poles carrying many wires. The poles should be inspected periodically and tested by boring (and the condition noted in each case, every pole being numbered). They should also be well braced and guyed when showing signs of weakness; they should be reset when loose, or renewed when decayed. The section foremen should know which is the division wire, and repair that first when the wires are down. Wires that are down should be strung on the fence or got out of the way of the track, and prompt report made to the superintendent, so that the linemen or repair gang may be notified at once. The section foremen should understand the imperative necessity of keeping communication open over the wires, and attending promptly to any defect or breakage. When the wire is broken, it should be released from one or two poles on each side of the break by removing the tie wires on the insulators, the broken ends being then united by a screw clamp. A proper joint is made by holding the wires lapping each other in the pliers and taking 5 or 6 short turns of each end round the other wire.

The poles are usually spaced 176 ft. apart, or 30 poles to the mile; sometimes 150 ft. apart, or about 35 to the mile (or 40 on curves). They are mainly of chestnut, red or white cedar. Cypress, redwood, spruce, Oregon pine or Norway pine are also used, the latter being usually for very high poles. They should be of sound wood, with the butt cut above the ground line of the tree; reasonably straight, thoroughly seasoned, peeled, and with the knots trimmed close. If painted or set in the ground when green, dry rot is sure to set in. For single poles, the diameter should be not less than 7 ins., and 20-ft. poles should be about 10 ins. diameter at 6 ft. from the butt. The butt is sometimes charred, or coated with tar to a point above the ground line, or a belt of tar is applied at the ground line. Experiments promise good results from treating the butts with preservatives in open tanks (see "Ties: Timber Preservation"). The earth should be well tamped around the poles, but not heaped up into a mound at the base, although a small pile of clean gravel or broken stone will keep weeds away and protect the pole from fire. Sometimes the poles are whitewashed. In Europe, the poles are very generally

treated with creosote, chloride of zinc and other preservatives. Such poles last from 25 to 35 years. Creosoted poles are commonly used in English telegraph work, and have been tried in this country, where they have been found in perfect condition, even at the butts, after 12 or 15 years' service. They are said to be good conductors, and are inflammable; for these reasons as well as the expense they are not used extensively for railway telegraph lines in this country. Iron poles are sometimes used, but are dangerous, as they are grounded conductors and likely to cause accidents to the lines and linemen. Concrete poles have been tried to a small extent.

The poles should be as low as possible, the minimum headway under the lowest wire being 12 ft., or 20 to 24 ft. at road crossings. Where sleet storms are frequent, double-pole lines may be built, the poles being 6 ft. apart at the bottom, meeting at the top, where they are fastened by a ½-in. bolt. Two 5½-in. poles may be used instead of one 7-in. pole. They may be braced at intervals, and on curves the outer pole should be anchored. In some cases the two poles are vertical, and connected by the cross-arms. Poles on curves should be inclined to resist the pull of the wire; and on curves and in exposed places where high winds prevail they should be supported by braces or by wire guys secured to anchors buried in the ground. The guys are likely to cause a leakage of current. Usually, every fifth pole has a wire lightning conductor, but on account of leakage of current, experiments were made in the way of abandoning these.* The results were so unsatisfactory that the use of the conductors is still almost universal.

The cross-arms are usually of pine or spruce, 3×4 ins., painted. Those for four wires or less should be secured by two lag screws, ½×6 ins., with washers. Longer arms have a ⅝-in. bolt and two galvanized iron braces. The arms are set in notches or gains in the poles. Wooden insulator pins are usually of locust, boiled in paraffin oil, driven into holes in the cross-arms and secured by sixpenny galvanized-wire nails. The iron pins are about ½-in. diameter, with a collar resting on the top of the cross-arm. The lower part of the pin is secured by a nut under the arm, and the upper part has a wooden sleeve fitting the insulator. The insulators are usually of glass, although in Europe porcelain is generally used. The middle pins are usually 22 ins. apart, c. to c.; the outer ones, 4 ins. from the end of the arm, and intermediate pins, 16 ins. c. to c. The wire is usually of No. 9 copper or No. 6 or No. 8 galvanized iron. The joints should be soldered. The sag for spans of 100 ft. and 150 ft. should be about 2 ins. and 4 ins. at zero, increasing 2 ins. for each 20° of temperature.

Where electric-light and power-transmission wires cross the railway, protection must be provided against broken wires. On the New York Central Ry., for voltages under 11,000 the electric wires must be carried underground by lead-covered cables in a vitrified-tile conduit 5 ft. below the ties. The conduit is embedded in concrete, and has a manhole at each end for the pole connection. For voltages over 11,000 the wires may be carried above the right-of-way, a cradle of copper wire being hung beneath them. Outside the fence on each side is a pole set 6 ft. in the ground, and having a cross-arm not less than 4 ft. above the top arm of the telegraph poles. The cross-arm is about 7 ft. long, parallel with the tracks, and is composed of two sticks, one on each side of the pole. At each end is an eyebolt, passing through a spacing sleeve between the sticks. Attached to the eyebolts are two No. 4 hard-drawn copper

wires extending across the track, and giving a clearance of at least 24 ft. at the middle. These are connected by No. 8 copper wires, 6 ft. apart, parallel with the rails, and having a sag of not over 6 ins. At the back of each pole, behind the cross-arm of the cradle, is a horizontal strut, with wire braces to the ends of the arm, and top and bottom braces to the pole. The cross-arm for the electric wires is 18 ins. above that of the cradle. In special cases, a steel bridge may be required to carry the transmission wires.

The following is an abstract of the official instructions issued by the Western Union Telegraph Co. in reference to the construction, reconstruction and repair of its lines:

The minimum depth that poles shall be set is 4½ ft. for 25-ft. poles, 5½ ft. for 35-ft.; 6 ft. for 40- and 45-ft., 7 ft. for 50- and 55-ft., and 8 ft. for 60-ft. poles. Where rock is encountered at 2½ ft. or less, the depth may be 1 ft. less than the above for poles 25 to 35 ft. long. In wet or marshy locations, or where the ground is likely to be softened by heavy rains, or where the poles are placed on slopes, they will be set at such greater depth that there will be no possibility of their being blown over or lifted by frost. In marshes, the butt of the pole may be set between two horizontal timbers (having crosspieces under their ends), with diagonal braces to the pole just below the ground line. In wet or marshy ground, every sixth pole should have a weather-brace or side-guy when there are not more than six wires; up to 16 wires, every third pole: over 17 wires, every other pole.

The tops of the poles must be wedge-shaped, the wedge being parallel with the wires. The slant of poles on curves must be gradual, so that the strain on the poles will be evenly distributed. All sharp curves and angles must be well anchored. Braces may be used for lines with not over 7 wires, where there is room and suitable timber is available. Braces must be set a uniform distance from the butt of the pole, at least 6 ft. when possible, with the top of the brace just below the bottom gain. In marshy ground, the brace must be framed with a foot of such area as to prevent its being forced into the ground. Anchors in solid ground must be set 4 ft. deep, and 1 ft. to 3 ft. in rock. The top of the anchor must project sufficiently for attaching the guy wire. The wire should never be fastened to the anchor beneath the ground. Office poles should be guyed in such a manner as to keep the strain of the wires off the office fixtures and front of building. Anchor wires must have three turns around the pole. One standard size guy wire is used for lines with 8 to 16 wires, one and two extra-heavy guy wires for lines up to 24 wires and 70 wires respectively. Two-bolt clamps are used for the first, and three-bolt clamps for the other two styles of guys.

Poles at corners and crossings (and the adjacent poles if there are more than six wires) must have double arms; and if spaced 30 to 50 per mile an intermediate pole must be set in the panels adjacent to the corner or crossing. Poles or anchor stubs must not be set less than 7 ft. from the nearest rail. When poles are fastened to stump poles, these must be from 8 ft. to 10 ft. long for 25-ft. to 35-ft. poles. The stump must be secured to the pole by lag bolts in the sloping top, and by wire wrapping at the top and below the ground line. To determine the necessity of resetting poles, attach a 1-in. rope to the pole at 5 ft. from the top and fasten the other end to the track rail, or some other stable object some distance away. If the weight of one or two men is then thrown on the rope (steadily to prevent shaking the wires), it will be demonstrated whether or not the pole is weak at the ground line. Long poles carrying a heavy load of wires will require the weight of two or three men to give a sufficient test, but it can be done in this way safely and without disturbing or crossing the wires.

Poles must be distributed from cars by using a ⅞-in. rope on the front end of the pole. One end is fastened to the second stake on the rear side of the car. The rope will be passed under and over the pole at about one-third from the front end, and then around the stake. This end is held by a man who lets out the slack while other men roll the pole off by cant hooks. The head of the pole will be placed at least 4 ft back, and the other end close to the side

of the car. Then with the rope on the pole there is no chance for it to get away as it is rolled off. Poles 25 to 40 ft. long can be handled safely in this manner. Longer poles will be handled with two ropes, and the train stopped until the back end of the pole rests on the ground. Three to four stakes must be used on the distributing side of the car, and in no case will the middle ones be removed, as that puts too much strain on the front stakes, and is dangerous. The speed of the train must not exceed six miles per hour. The openings between the cars must be covered to prevent men from slipping through to the track. Linemen must not distribute poles with less than two men to assist, and with only two men the car will be placed behind the caboose.

Gains for cross-arms must not exceed $\frac{3}{4}$-in. in depth in sawed redwood poles, nor $1\frac{1}{4}$-ins. in round cedar poles 6 ins. or less in diameter at the top. Where cross-arm braces are used, the gains should not exceed 1-in. The distance from the upper side of the top gain to the extreme top of the pole will be 8 ins., and the gains must be 2 ft. c. to c. When arms are added to a pole, they must be spaced the same as the old arms. Double arms should be used on office poles, at corners, at railway or river crossings, and on unusually long sections. Cross-arms will be fitted only with sufficient steel pins to accommodate the wires already on the line, or additional wires that are to be placed immediately. Two bolts will be used in all arms which are not braced. Braces will be used on arms 8 ft. long (or more) and carrying 6 or more wires. In new work the arms must be faced alternately in opposite directions, except when it is necessary to face them in a certain direction in order to have the arms pull against the pole, as where bridle or line guys are used. Cross-arm fixtures should be attached to office buildings with bolts passing through the wall, or with expansion bolts, instead of being attached to door or window casings. Screws must not be used, as they are liable to pull out under a heavy strain. When double arms are used, they are secured by bolts through each side of the post and a bolt at each end (with wooden blocks between the ends).

The wire must be tied on the side of the insulator nearest to the pole; on curves or corners it may be necessary to place the wire on the opposite side so that it will draw against the insulator. The full-sized line wires should be carried to the inside of the building from a fixture attached to the wall, equipped with standard glass-and-pin insulators. The wires will have an upward direction from the insulators, to prevent rain and moisture from following them to the wall. Where exposed wires run into the building, they will be covered with a sloping roof board of sufficient width to protect them from rain and snow, and where they pass through walls and partitions, they must be insulated with tubing of sufficient length to go entirely through the wall. At telegraph offices located in railway stations, or similar long buildings, the wires must enter at the window or other opening nearest the switchboard, and must be so strung that they can be plainly seen and easily inspected. All splices must be soldered, except on copper wires, for which McIntyre sleeves will be used. All connections between copper and iron wires must be soldered. Wires inside buildings must be insulated on porcelain knobs or cleats, and kept as far apart and as far from the "ground" as possible. The use of staples for attaching office wires is forbidden. Porcelain insulators and knobs must not be used outside of buildings, except where covered wire is used. All connections in main battery wires must be soldered, and the wires insulated. Permanent terminal ground wires must be composed of No. 8 copper wire, soldered to the main gas or water pipes.

Lightning conductors of ordinary line wire will be placed upon poles adjoining office poles. Also on every fifth or sixth pole where there are from 1 to 12 wires and the poles are spaced 30 or 35 per mile respectively; on every tenth pole for over 12 wires and 35 to 70 poles per mile. About 10 ft. of this wire will be formed into a flat coil and placed under the butt of the pole. The other end must be stretched up the pole and fastened by 12 or more wire staples. It will be extended about 7 ins. above the top of the pole and the end then turned back and fastened to the pole, making a projection of 3 ins., with three turns or twists. On bracket lines, the ground wire must be attached to the pole one-quarter of the way around from the bracket, so that if a second wire is put on the opposite side, neither of the line wires can touch the ground wire if detached from the brackets. On cross-arm lines, the ground wire will be attached to the pole on the side opposite to the cross-arm.

Wires must be kept at a height of not less than 25 ft. at railway crossings, and 18 ft. at public or private highway crossings. State or railway regulations must be followed when they conflict with this rule. Where the telegraph wires are crossed by other wires, the poles of the span thus crossed have additional cross-arms near the top, carrying two No. 8 guard wires, which are attached to strain insulators at the tops of the next adjacent poles. Aerial cables must be supported by carrier wires, from which they are suspended by a spiral cord or by clips. They must be 30 ft. above railway crossings.

All poles and anchors will be set before transferring wires. Use a measuring wire of the required length to locate the poles the proper distance apart. This wire will have a handle on one end, and a foot of chain on the other end to keep the wire straight as it is dragged over the ground. It must be examined carefully every morning, to see that it has not been lengthened or shortened from any cause. When, owing to the nature of the ground or other reason, it becomes necessary to vary the distance between poles, the distance will be carefully measured and adjacent sections will be varied sufficiently to compensate for the change, in order to insure the proper number of poles per mile. All holes must be dug to the full regulation depth, and large enough to permit the full use of tampers. Poles must be well tamped, with not less than three tampers and not more than one shovel in the setting of any pole. After the hole is tamped even full, the remaining dirt will be banked up around the pole at least 12 ins. high, with a proper slant. If there is not enough loose dirt, it will be taken from not more than two places, at least 6 ft. from the pole and directly in line with the wires. It must not be taken from either side of the pole, as reelmen or climbers might fall into the depressions.

Hand cars must be used as much as possible in moving hole diggers. One man in each digging gang will follow the work to take out the last few inches of dirt in each hole and see that it is of a proper depth. When the ground will permit, post augers will be used. They are quicker than shovels or spoons, and can be used when the hole has reached a depth of 2½ ft. The opening can be enlarged when necessary by the use of slicks, and the dirt thus removed from the sides of the hole can be lifted out quickly by the use of the auger.

The line will (unless otherwise directed) be located within 4 ft. or 5 ft. of the right-of-way fence, thus leaving room for the passage of reel-carriers between the fence and the poles. When a pole-pulling machine is used, the machine must be placed on a board to give it a bearing, and then set straight up beside the pole or stump which is to be pulled. The pole or machine will be held straight by a line or temporary brace to prevent binding the pole against the side of the hole. The gear of the pole-puller must be well oiled and kept free from sand or dirt. The brace will not be removed from a braced pole which is reset, but sawed off the required length from the ground so that it will come properly into position when the pole is cut off and lowered into the hole. Side lines must be employed when poles are to be set in difficult places or on side hills or banks. When poles are to be lowered or taken down, two side lines will be used, one on each side, to prevent the pole from swinging.

CHAPTER 26.—PERMANENT IMPROVEMENTS.

The improvement and reconstruction of existing railways has been a conspicuous feature of engineering work for the past few years, and its importance is steadily increasing. It represents a distinct class of work, and the engineering work of existing railways may be classed as follows: 1, Construction of extensions and branches; 2, Maintenance-of-way and structures; 3, Construction of improvements or betterments. The reconstruction or improvement is generally undertaken owing to changed conditions resulting from developments in traffic and competition; it is rarely due to defective original location or construction. Many lines were originally built in thinly

populated districts and with special regard to low cost, rapid construction, and light traffic. As these lines become more important, the heavy traffic is operated at a disadvantage. Even on lines of heavier construction, the growth of traffic and increase in train loads often necessitate the strengthening of structures, the provision of additional tracks, or the modification of grades, in order to give greater facility and economy of operation. In other cases, where a line encounters competition, an improvement in line and grade may be desirable for the increased safety and comfort of fast passenger trains, even though little may be gained in facility or economy of handling traffic.

The improvements may include general reconstruction, and also the introduction of heavier bridges and track to carry heavier engines and train loads. They are of varied character, the principal being as follows: 1, Reduction of grades and curves; 2, Double tracking, and the provision of additional tracks, sidetracks and passing sidings; 3, Shortening distance or avoiding congested terminal points (at cities) by direct lines and cut-offs; 4, Increasing yard and terminal facilities, for both passenger and freight service; 5, Bridge renewals; 6, Widening embankments and cuts; 7, Replacing timber and old structures with solid embankments or with new structures of steel or masonry; 8, Track elevation or depression to eliminate grade crossings; 9, Building new stations, shops, water and coaling plants; 10, Installing signals and interlocking plants. Space does not permit of any extended treatment of the subject, but bridge work, signaling, drainage, and yards and terminals have been discussed in previous chapters. It is easy to estimate the cost of an improvement; it is usually difficult to estimate or to determine definitely the reduction in operation which it may effect. This matter is dealt with in "Engineering News," Aug. 31 and Sept. 14, 1905, and April 4, 1907. Its economic side is discussed very comprehensively by Mr. J. B. Berry in a paper on the improvement work on the Union Pacific Ry., in the Proceedings of the American Railway Engineering Association, 1904.

The execution of work of this kind calls for careful and systematic organization, and considerable ingenuity in devising methods of working under difficulties, in order to facilitate the progress of the work, to keep the cost within limits, and to avoid interference with traffic. An example of this is afforded by a section of track elevation work in Chicago. This consisted simply in building retaining walls, putting plate-girder bridges over the streets, and filling in with sand or earth. But the piece of line included two double-track main lines approaching city terminals, and constantly in use for regular and light trains, engines and switching movements. A passenger-car yard, a small local freight yard, and spurs to industrial works were involved, while the work was complicated by the switch and signal equipment, interlocking plants, grade crossings, etc. Accommodation for the passenger and freight cars had to be provided farther out, which in turn increased the traffic, as all light or empty passenger trains had to be run over the track elevation work. Then the main tracks had to be shifted from time to time to allow of building the side retaining walls and the bridge abutment walls at street crossings. Piles also had to be driven in and between the tracks, and temporary trestles erected across the streets. Every change of track necessitated changes in frog and switch work, in signals, and in all the mechanical and electrical connections. In addition to this, plans had to be studied out for delivering and handling the construction materials, mixing and depositing concrete, handling and

placing stone blocks and bridge girders, hauling away the earth excavated from foundations, and later on bringing in the filling. Changes in water and gas mains and sewers were also involved. All this must be done so as to give the greatest economy, facility and safety for carrying on the work without interfering with or endangering the safety of the regular traffic. Practically the same conditions obtain in grade reduction, double tracking, etc. Engineers in charge of work of this kind must possess not only professional skill, but also executive ability, readiness to meet emergencies, and familiarity with operating conditions. It is generally recognized that the railway should have one man in responsible control of both construction and traffic for the entire work, whether it is done entirely or in part by railway or contract forces.

In reconstruction work on the open line, such as double-tracking or realinement, which will interfere with existing tracks, it is a difficult problem to avoid either hampering the contractor or interfering with the traffic. In some contracts a penalty is provided for delaying trains, but this is rarely satisfactory. In some work on the Lehigh Valley Ry., the penalty was for delays exceeding 5 or 10 minutes (for different classes of trains), thus allowing the contractor sufficient time to get clear of the tracks. In double-tracking the busy line of the Union Pacific Ry. between Kansas City and Topeka, the work was so complicated that it was found impossible to apply a satisfactory penalty provision, as the contractors would have raised their prices considerably to meet the conditions. The plan adopted, after conference between the engineers and contractors, was to put a flagman at the steam shovel and one at each end of the section of work. These men governed train movements by hand signals and the plan proved entirely satisfactory to the engineers, the transportation department and the contractors. The men worked under the railway company's orders, and their wages were paid by the contractor. A similar plan was employed in realinement and grade reduction where the new and old lines crossed six times in 11 miles, at the same or different grades.

In many cases of this kind, the handling of both regular trains and work trains may be greatly facilitated by establishing a telegraph office or block-signal tower at the work, the operator having telephone or other communication with the men at the switches at each end of the section. According to the extent of the work and the traffic, the operation may be under the control of the transportation department of the division, or the section on which work is being done may be operated as an independent division having its own dispatcher and trainmaster. In some work on the Grand Trunk Ry., in Michigan, there were three telegraph offices in about 2½ miles. At each of these was a semaphore, and all work trains were under the protection of the semaphores, regardless of orders. These trains were in no way handled by dispatchers. The operator at the center tower instructed the office east and west of him when to block trains. For example, when a train of material left the steam shovel to go west, the operator at the center tower notified the one at the west tower, and the work train moved in this block section regardless of all trains. With three crews, 300 cars could be taken from the shovel and unloaded on main line without interfering with the traffic, which averaged in working hours about 8 to 12 trains each way per day.

In planning the improvement, the aim should be to secure the easiest grades and curves economically adapted to the physical conditions and the prospective

traffic conditions. The location should be finally determined before commencing construction work. In arranging for the execution of the work, it is important for the man in responsible charge of the entire work to plan a general system of procedure. The relative position and order of the steam-shovel cuts, the position of loading tracks, the methods of controlling trains, and all features of the work should be determined in advance, and the plan followed out. In the constant shifting of tracks at least one running track should be kept open, and not disconnected until some other track is connected up. The arrangement and connections of tracks must be carefully planned, and it may require a large gang of men to shift the tracks and make or cut connections as required. Ballasting and track work are best done by the railway, the contractor completing the line to subgrade. It is desirable to have an entire separation of tracks for regular trains and work trains, but this is not generally practicable. In a report of the American Railway Engineering Association (1908), it is stated that when the excavation and embankment are within moderate reach of each other, it is best to provide separate tracks for the work trains. If they are so far apart that miles of track must be used jointly, then separate tracks should be laid for the terminals of the work. In some cases an entirely new line may be located along the old one, or a temporary roadway may be built to carry the traffic clear of interference with the work. This is specially the case for work on single-track roads. The importance of the traffic will determine the expense which will be justified in providing a temporary running track, and in some cases it is practicable to shift the alinement and put the temporary line far enough away to permit of the reconstruction on the original line without interfering with the regular traffic.

Some notes on the principal classes of improvement works are given below. Minor improvements of the same character, but on a smaller scale, may be carried out by the maintenance-of-way department. Such work may include the following: (1) Filling sags and flattening summits (due to settlement of earthwork or bad arrangement of grades); (2) Slight but general changes of curvature throughout the length of a railway or a division; (3) Widening banks; (4) Extending passing sidings. Such improvements may be undertaken on general principles (if the result will warrant the outlay), or to put the road in better condition to meet competition.

Improvements in Alinement and Grades.—Many railways have undertaken extensive realinement to effect a saving in distance and curvature, the latter being particularly important on high-speed passenger lines. The work is practically similar to new construction, but care must be taken to properly connect the old and new work where the two locations cross or meet, and to effect the changes in track without interfering with the traffic. Grade reduction has also been carried out very extensively, in order to enable heavier trains to be hauled, or to enable trains of maximum load to run through without being divided or assisted by pusher engines. In most cases the alinement has been improved at the same time. The work usually combines the cutting down of summits and the raising of sags, and involves considerable difficulties in carrying on the work rapidly and economically without undue interference with traffic. The Wabash Ry. a few years ago completed improvements on its line between Chicago and St. Louis by which the ruling grade was reduced from 1% or 1.15% to 0.4%, and 390° of curvature (2½ miles of curved line) were eliminated. In another case the reduction of grades from 1% to 0.6%,

and the reduction of all curves over 3°, enabled engines to haul 1,500 tons instead of 1,000 tons, and with practically the same fuel consumption.

The Columbia River line of the Oregon Ry. & Navigation Co. was built to follow closely a supported grade along the river, involving numerous curves, but resulting in rapid and comparatively cheap construction. Traffic development has led to the improvement of this line, and the work consists largely of straightening. This is done mainly by building straight across between the projecting points, avoiding the numerous inward curves to follow the foot of the hill and also avoiding the curves around the extremities of the points. Between Troutdale and Bonneville, 18 miles, a saving of 950 ft. in distance was effected, the summit was lowered 25½ ft., the maximum grade was reduced from 1% to 0.35%, and the sharpest curves are 3° instead of 10°. The striking feature is that 1,455° of curvature are eliminated, and in one place a tangent eliminates eight curves. The work on this line and on the Chicago Division of the Cleveland, Cincinnati, Chicago & St. Louis Ry. is described in "Engineering News," May 16, 1907. The Norfolk & Western Ry. in improving its line, to facilitate freight traffic and to allow of safely increasing the speed of passenger trains, reduced its 8° and 12° curves to 6°.

Double-Tracking and Additional Tracks.—The double-tracking of main lines is a most important improvement, increasing the traffic capacity and relieving congestion which causes continual trouble and delay ("Engineering News," Sept. 14, 1905; April 4 and Aug. 29, 1907). A double-track line has a much greater capacity than two independent single-track lines, and has a higher degree of safety, as there are no opposing trains to be considered, and the number of facing switches can be reduced to a minimum. On single-track lines of heavy traffic, the trains may spend a considerable proportion of their time on sidetracks, waiting for opposing trains, which latter may often be late and so increase the delay. With a double-track line, the only road delays would be those due to taking the sidetrack in order to allow superior trains to pass in the same direction. Thus a smaller number of engines might be able to handle a much greater amount of traffic, and with greater promptness and economy. Not 10% of the total mileage of the railway system is yet double-tracked. While only the lines carrying heavy traffic require double-tracking, it may be reasonably estimated that the proportion should be 20 to 25%, so that there is a decided deficiency even on lines of this class. This means that in many cases a "double-track traffic" is handled on a single-track line. As a rule the work consists in widening banks and cuts for a parallel track, but in many cases the opportunity is taken to improve the alinement and profile at the same time. A new double-track cut-off may replace an old piece of less favorable single-track line, or the second track may be built in part (for topographic or operating conditions) on a different location ("Engineering News," Nov. 21, 1907). On some busy lines, especially near large cities and where suburban traffic is heavy, four or six main tracks may be necessary. Somewhat similar work is the construction of long passing sidings or relief tracks to facilitate movements on single-track or double-track railways. Near large terminals, separate tracks may be built to the yards, thus relieving the main tracks. For three miles out of Omaha the Union Pacific Ry. has two tracks for through passenger and freight trains, and two for trains going to and from the yards.

Enlarging Cuts and Banks.—This work will be included in most of the improvements noted. In widening shallow cuts, scrapers may be employed.

Where cuts must be widened and deepened, the main track is very generally used for the work trains, if the traffic is not heavy. The steam shovel widens one side and cuts to the new grade. A running track may then be laid in the new cut, while the shovel makes a second cut on the other side, the old track still serving for work trains. A third cut takes out the old roadbed and finishes the work to the new grade. With deep cuts, the upper part must be widened before the lowering to the new grade is done. In widening and deepening cuts, special attention should be given to the drainage, and tile drains are generally laid. Such drains may also be laid at the toe of new embankments to drain the ground. In building banks with wet or soft material and in wet weather, careful watch should be kept for slips and settlement, and trains should not be allowed to run at high speed over such banks.

New banks, or the widening of old banks, may be built by dumping from cars on a temporary track, and jacking up the track by successive lifts. This is mainly for banks of not over 5 ft., and is rarely done in widening except where the traffic is so heavy that main tracks cannot be occupied. For higher banks, temporary trestles are generally built. In double-tracking, the new part of the bank may be built to the new grade, and a running track built upon it, the old track being then abandoned and the bank raised. For high banks it is a good plan to put aprons on the sides of the cars and of the trestle so as to throw the material to a distance. In this way the material will fall towards the sides of the bank and roll back to the center, making it much more solid than if the material is dumped in a single center ridge. The Chicago & Northwestern Ry. has built some very large and high banks from two parallel trestles 80 ft. apart, with traveling aprons on tracks below the top. Half of each apron was twice as long as the other, so that the bank was built up in the form of eight ridges, making the completed bank very solid. In some cases scrapers are used to spread and level the material as it is deposited (see "Filling Trestles"). In widening old banks, the ground should be cleared, as in new work, and a trench cut to give a footing to the new slope. The face of the old bank should be stripped of grass and weeds, and stepped or benched so that the finished bank will be homogeneous. If the material is simply dumped over an old and compacted slope, it will be liable to continual sliding, owing to lack of bond with the old material. After heavy rains, long cracks will appear at the top and large masses of the new material will break away from the shoulder. The material can be distributed by dumping or plowing from cars, and leveled by a spreader car. Methods and equipment to be used in work of this kind are discussed in "Engineering News," Aug. 9, 1906; Jan. 17, April 11, and Aug. 29, 1907; and the Proceedings of the American Railway Engineering Association, 1907. Methods and examples may be studied with profit, but each piece of work presents its own problems and features, and the best solution must be arrived at by the co-operation and consultation of the engineer and the contractor.

Filling Trestles.—A class of work which is in constant progress on many railways is the replacing of timber trestles with solid banks, providing pipe or masonry culverts for the necessary waterway. The great extent to which timber trestling has been adopted in this country is one of the principal factors in the economy and rapidity of construction which have been characteristic of American railway work. The use of such temporary structures has been justified by the necessity of keeping the first cost of the railway as low

as possible, and by the importance of enabling the line to carry traffic as soon as possible. While well-built trestles are safe and substantial structures, their life is limited, the cost of suitable timber is increasing, and the cost of maintenance and repair is considerable. They are also liable to damage or destruction by fire and flood, and are an element of danger in case of derailment (except where a ballasted floor is used). In case of flood, it is very dangerous to run trains over a trestle, and it is very difficult to determine its condition. Trestles over waterways liable to floods should therefore be replaced with permanent structures. In almost every case it will be wise economy to provide for gradually replacing all trestles with solid embankments, which will ordinarily require no inspection or maintenance. Material excavated in making other improvements may be utilized for this purpose. The cost of such work is described in the Proceedings of the American Railway Engineering Association for 1907.

Earth, gravel and clay are generally used for filling. Soft or wet clay is to be avoided, as it will slip and settle for many years, and the maintenance of the bank may be more expensive than that of the trestle. Furnace slag and the refuse from coal mines are sometimes available. The material is sometimes put in by scrapers; but generally it is shoveled, dumped or plowed from cars. Aprons may be used to throw the material to each side (as noted in regard to widening banks). In this way as the bank becomes higher and the pressure greater, the earth rolling back towards the center will cause less damage to the structure than when dumped close to it. Care must be taken that the posts do not spread under the lateral pressure. If there are boulders in the material, an open plank screen (like a picket fence), inclined downwards from the edge of the trestle, will cause all such large material to fall clear of the trestle bents and form the toe of the bank. In a few cases, a temporary track for the gravel trains has been built on each side of the trestle. In filling some high trestles on the Chicago & Northwestern Ry., the material plowed from trains was leveled and spread over the entire width by drag scrapers and teams, slope stakes being set as the work was carried up. In this way the bank was built in horizontal layers. The cost was little more than that of letting the material form ridges in the usual way, and there was no expense for subsequent maintenance work. Other banks built in the ordinary way, and with the same material, slipped and settled considerably; these required additional material to bring them to grade.

A long trestle deficient in longitudinal bracing should not be filled from the ends or from one end, as the pressure may result in the injury or collapse of the trestle. Temporary sash braces may be put on, and removed as the filling rises. The filling must be carried on uniformly along the entire length, thus maintaining a practically horizontal surface for the bank and preventing the straining of the structure. On such a trestle, care must be taken not to impose severe longitudinal strains by too free a use of the air brakes on the gravel trains. If the earth or gravel is to be plowed off the cars in the usual way, the strength of the trestle is an important consideration in regard to the resistance to the racking strains, and to the lateral strains if a side plow is used, especially if the material is stiff and the cars are chained to the track. A plow being hauled over a car and suddenly striking a boulder or other obstruction may throw very severe strains upon a trestle. This is more particularly the case where the trestle is on a curve. The strains may be consider-

ably reduced by using a plow operated by a winding engine on the front car. (See "Ballasting.") To facilitate the work and to avoid the difficulties (and the dangers to the men) of operating ordinary dump cars on trestles, dump cars operated by compressed air are extensively used. The operating cylinders are connected to a train pipe and are controlled from the cab of the locomotive.

The trestle bents must, of course, remain in place, but while the work is in progress, the bracing and horizontal timbers should be removed as far as possible, so that the filling may be homogeneous and any settlement or shifting of the structure will not affect the embankment as a whole. If the work is done in the autumn, the ties, stringers and floor system may be left in during the winter, and removed in the following spring, the bank being then filled to grade. On some roads the caps are removed also.

On soft ground and steep slopes, the work of filling calls for careful investigation, and in marshy ground an enormous amount of material and work may be required to obtain a permanent bank. In extensive work of this kind on the Canadian Pacific Ry., the soft ground was practically unfathomable, and swallowed up all of the filling. The successful expedient was adopted of using light sawdust instead of heavy gravel. In other cases the soft material rested upon a sloping rock bed, down which the bank would slide. The alinement was sometimes changed to avoid the most troublesome and dangerous places, and it was sometimes possible to get a better location on firm ground than the original location on treacherous ground. But as a rule the difficulties were steadily fought until overcome. Another expedient is to cover the ground with a floor or mattress of logs. Such work should not be commenced until careful soundings and investigation have been made as to the character of ground, depth and slope of hard bottom, etc., and a proper plan then devised in accordance with the conditions to be met. Otherwise the result may be the loss of money, time and material, or perhaps the distortion (or even wrecking) of a structure and a costly interruption to traffic. The dumping of material in a swampy bottom or a sinkhole may develop unexpected upheavals in a more or less distant part, which may lead to damage suits or involve the compulsory purchase of land.

Hydraulic filling may be employed where water is obtainable under considerable head, usually about 200 ft. The water in 3-in. or 4-in. jets breaks away the material, the water and earth being then carried to the trestle by a flume. The flow is directed to any desired point by troughs, and stop planks may be used to hold the material while the water drains and flows away. To check the flow and increase the deposit, a line of old ties or a 6-in. to 12-in. dam of marsh grass (faced on the inside with earth) is placed along the edge of the bank. This forms a pool, the material settling, and the water flowing quietly over the bank. This is renewed on the slope as the pool fills. The ties and grass protect the slope, while the latter grows and eventually forms a sod. The progress is usually slow, but the bank thus made is very solid and stable The filling is carried up to within 4 ft. of subgrade, the bank being then finished by work trains. This method has been used for filling trestles on the Canadian Pacific Ry. and the Northern Pacific Ry., and for building banks on the Pacific extension of the Chicago, Milwaukee & St. Paul Ry.

Low-Grade Tunnel Lines Replacing High-Grade Summits.—In several cases railways have been carried over mountain ranges by summit lines, for

economy in first cost and for promptness in completing the road. Increase in train loads and traffic, high cost of operating steep grades, and sometimes difficulties from snow, have in some of these cases led to the construction of a cut-off and tunnel, at a lower elevation. The Northern Pacific Ry. crossed the Cascade Range in 1887 by a switchback line 7 miles long with grades of 5.6%, compensated 0.04% per degree, and having tail tracks of 0.2%, 400 to 500 ft. long. The summit elevation was 3,675 ft. The Stampede tunnel line reduced the distance to 3 miles, the grade to 2.2% and the elevation to 2,827 ft. The Great Northern Ry. crossed the same range by a switchback line 12 miles long, with grades of 3½ and 4% (compensated 0.04%), and 12° curves. The summit elevation was 4,055 ft. The Cascade tunnel reduced the distance to 3½ miles, the grade to 1.74 and 2.2%, and the elevation to 3,350 ft. On the Colorado Midland Ry., the Busk tunnel saves 7 miles in distance, 530 ft. of elevation and 2,000° of curvature, as compared with the summit line (which has no switchbacks). The Zigzag tunnel line on the New York, Ontario & Western Ry., about 1 mile long, replaced a switchback line with four inclines, about 3 miles long, and saved about $30,000 per annum (formerly expended in helping trains over the summit), or more than thrice the interest on the cost of the tunnel. The incline grades were 1.98% for southbound trains, and 1.8% for northbound trains, while on the tunnel line they are 1.25 and 0.75% respectively. (See "Switchbacks.")

In this connection reference may be made to the two lines between Salt Lake and San Francisco: (1) The Central Pacific Ry., built as a link in the first transcontinental railway and with the one main object of effecting the communication at a minimum expenditure of time and money, at a time when the traffic prospects were very limited; (2) The Western Pacific Ry. (1906–08), built with a view to economical operation of important traffic. The first is 780 miles long from Ogden (820 from Salt Lake), and has a long stretch above the snow line, with some 40 miles of snowsheds; its maximum grades are 2% and 2.2% at the summit and 1.35% to 1.5% elsewhere. The latter is 930 miles long, with no snowsheds, maximum grades of 1%, and a summit elevation (5,000 ft.) nearly 2,000 ft. lower than that of the older line. On the other hand, it has numerous tunnels and other heavy works, the cost of which is considered to be well warranted by the improved operating conditions. A suggestion has been made for the Central Pacific Ry. to meet the competition by building a tunnel of great length and cost to obtain a summit elevation even lower than that of the new line. As an alternative, electric traction on the heavy-grade sections has been suggested. Submarine tunnels to eliminate ferry transfers for trains have been built at New York, Port Huron and Detroit.

Track Elevation.—In many cases railways were originally built through cities and towns on the street level, but with the growth of railway and street traffic the dangers and inconveniences due to the numerous grade crossings have led to the elevation (or sometimes the depression) of the tracks. This work is very expensive, but it gives the railway an uninterrupted right-of-way, and avoids the expenses incident to crossing gates, watchmen, liability for damages, etc. In many cases the streets are lowered so as to reduce the height of elevation, and the work involves the renewal or removal of water and gas mains, sewers, street railways, etc., and the repaving of streets. The work is of a special character, and calls for careful planning and organization in order to avoid excessive cost and time in execution, to avoid accidents

and to prevent interference with either railway or street traffic. In the extensive work at Chicago different methods have been employed. On the Chicago & Northwestern Ry., derrick cars drove piles for longitudinal retaining walls and transverse abutment walls; the trenches for the foundations of the latter were sometimes spanned temporarily by longitudinal timbers under the rails. On the concrete foundation of the former a track was laid for a derrick car handling the stone blocks. The track next to the wall (No. 1) was given up to work trains. Where the wall was of concrete, work trains with supply cars and concrete mixers were stationed on this track. The concrete was deposited by a drop-bottom bucket handled by a derrick car in front of the concrete-mixer car. The streets were crossed by pile trestles, built for one or two tracks at a time. As each street was bridged, the approaches for track No. 1 were raised by sand from work trains; these then ran upon the track to continue the filling. The grades were as steep as 5% for the work trains, and 2% for the passenger trains. When track No. 1 was completed, the piles for track No. 3 were driven; track No. 2 was abandoned (the ties and rails tilted upon end), and the bank of track No. 1 widened by dumping sand from trains on this track. The old No. 2 track (with joints cut) was then pulled up by derrick cars and laid as elevated track No. 2. This then became the work track, and track No. 1 was turned over to the transportation department. The other tracks were raised in succession in the same way. The abutment walls were then built between the rows of piles, and the girders and floors of bridges were set in place on one track at a time, this track being used for traffic as soon as the work was completed. The sand was brought in by trains of 30 to 40 cars of 40 tons capacity (average load 33 cu. yds.); these were broken up into sections of 6 to 12 cars, which were backed onto the work track and unloaded by shoveling.

The work of the Pennsylvania Lines in Chicago was done in a generally similar way. The trestles for track No. 1 (against the wall) were built to half height, temporarily blocking one or two streets at a time. Sand was then filled in as high as possible from trains on No. 2 (on the old level), and No. 1 was relaid on the bank (at half height). The trestles for No. 2 and No. 3 were built to full height. Sand was unloaded from No. 1 and this track jacked up and raised gradually, extra caps being put on the trestles as the work progressed. The bank was then widened from the side by trains on No. 1, but to avoid covering the low-level running tracks on narrow right-of-way, cribbing of old ties was built parallel with these tracks to act as temporary retaining walls for the filling. ("Engineering News," January 11 and February 22, 1900; March 9 and September 7, 1905; July 5, 1906.) Some railways do nearly all the work by their own forces. Others have more or less of the work done by contract. The American Railway Engineering Association recommends that the railway should do all work which may interfere with operation. It also recommends that there should be a superintendent of construction in complete charge. To him should report the engineers having charge of the contract work, lines and grades, masonry and bridges, the roadmaster in charge of earthwork and track work, the yardmaster in charge of engines and switching, and the trainmaster (with a dispatcher) in charge of the operation of traffic over the territory covered by the work.

Resurveys.—A different class of work is the entire resurvey of a railway line to check its maps, profiles, monuments, land boundaries, etc. This is

often an economic necessity for the purposes of the engineering, right-of-way and legal departments. In many cases, maps and records are incomplete, especially as to changes in location made during construction (which may affect the property lines, and the position of mile posts), and as to subsequent additions and changes in yards and sidetracks, right-of-way, etc. This work, as carried out on 600 miles of railway, has been fully described by Mr. Hosea Paul in a pamphlet on "Railway Surveys and Resurveys." In 1896 Mr. George D. Snyder presented to the American Society of Civil Engineers a paper on "The Resurvey of the Williamsport Division of the Philadelphia & Reading Ry."; and the subject was discussed in "Engineering News," April 14, 1904.

Construction and Work Trains.

The permanent improvements noted above, and the general improvements which are continually being carried out by the maintenance-of-way department involve the extensive use of construction or work trains. These must be handled promptly and efficiently in order to combine proper service and a minimum interference with regular traffic. Some particulars of their work have been given above and in Chapter 18. The operation of these trains has been a very weak point in railway service, and in spite of rules and regulations they are not unfrequently an expensive feature (owing to the small amount of work accomplished in a day), and a menace to the safety of traffic and the working gangs. The work train is often regarded by dispatchers and train crews as a sort of necessary nuisance, to be kept out of the way as much as possible. Even superintendents have this idea sometimes, but under the division system the superintendent (being in charge of both the roadway and the transportation departments) will better realize the importance of the train and provide for its efficient operation. When the work train is sidetracked to wait for belated trains, the pay of the gang of perhaps 25 to 50 men goes on, but without any return; and perhaps a steam shovel will be held up for lack of cars. On large pieces of reconstruction work, these conditions are not likely to exist, due to the special organization of work and the better equipment of the trains. They are more likely to exist in the handling of the ordinary work train (which is often made up of second-rate engines and equipment), engaged in distributing ballast or ties, filling trestles, cleaning ditches, etc. The delays may often be remedied if the dispatcher is given to understand that the work train is an important and expensive item in the maintenance account and should be operated and protected in such a way as to enable it to work the maximum time without interfering with or endangering traffic. The equipment should be such that the train can be safely run as a section of a passenger train. On the Atchison, Topeka & Santa Fé Ry., the trains have sometimes a telephone outfit for communication with the telegraph operators at stations.

A work train is usually given train orders authorizing it to occupy a specified portion of the track as an extra, and no other irregular train should then be authorized to pass over that portion of the track without provision for passing the work train. If it is anticipated that a work train may be where it cannot be reached for meeting or passing orders, it may be directed to report for orders at a given time and place. Work trains occupying the main track on a line operated under the manual-block system, must inform the signalman at the entering end of the block (or at both ends on single track), and leave

a flagman at the tower. Regular trains will then be stopped, and allowed to proceed with a "caution" card. Where work is in progress at some distance from a station, a temporary telegraph station or bell-code station may be established at the gravel pit, and the men in charge of the train kept informed as to train movements. The roadmaster or other officer in charge should see that the gravel trains are unloaded as quickly as possible, the rails properly cleared, and ballast or filling leveled off so as not to strike car steps, brake beams, etc. The train should be sent back or got out of the way promptly when unloaded. It is generally advisable to keep one train of cars in the pit, while the other is out on the track. In distributing rails, ties, etc., the roadmaster should designate points for unloading, so as to avoid rehandling of the material. The handling of work trains in connection with general improvement work and bridge renewals has already been noted.

The foreman of the construction gang should act as conductor of the train and share with the engineman the responsibility of its safety. A conductor who has nothing to do with the work is more likely to hinder than to help. The foreman acting as conductor gets a knowledge of the train service which enables him to arrange his work to better advantage, and to do the smaller items of work (which consume so much of the train's time) between the time of certain trains. He must be an expert foreman, qualified in all branches of track work. He should have an assistant foreman and a timekeeper if his force is large. He is responsible for seeing that the cars are in good running order, and must make reports of all track material delivered, work done, and delays experienced. Work-train reports are discussed under "Reports."

The conductor and dispatcher should work in harmony. The former will notify the dispatcher as to the location of his work, the time it will probably require, and his movements when the work is finished. The dispatcher will inform the conductor as to expected movements of trains, especially of expected extras, so that he can report at a telegraph station in time for orders. It often happens that the work train is tied up by signals on regular trains to enable the dispatcher to run other trains as sections of the first, when they could be run as extras. The limits of the work train should be as short as possible, as the dispatcher can handle it better. Where the track is crooked and traffic is heavy, the work trains should not be allowed to work under flag on the time of freight trains. A work-train conductor working on limits should not run past telegraph stations on the way to sidings without ascertaining the times of regular trains and whether the dispatcher can assist in any way. On the other hand, dispatchers should be held strictly accountable for delays to work trains.

On the Lehigh Valley Ry., the work-train crews are in the roadway department, and each crew consists of an engineman, fireman and one to two brakemen. These men are selected with great care and are considered experts. As the work train is important (from being in the way of all extra trains), and as the traffic is very great, the best men are necessary for the most effective working. There is also a man who acts as conductor and foreman, being selected from the roadway force of the division. He is qualified to do all kinds of construction and repair work in the roadway department and is required to pass the regular conductor's examination. There is also an assistant foreman, and with more than 40 men a timekeeper is assigned to the gang. The work formerly done by floating gangs is now done by the work-train gang,

which is an improvement, as the material for the floating gang was handled by the work train, and this train was often put to a disadvantage in taking that gang to and from work. Work-train extras are assigned working limits by special telegraph orders, in accordance with the standard code. They are required to clear first and second-class trains by 10 minutes. Most of the freight trains are run as extras, and in such cases the work train works until overtaken, being protected by a flagman. When schedule trains are late, the work train is given time on the delayed train, the same as any other extra. The work-train gang may assist the track gangs at times, as in reballasting when waiting between trains. On the Wisconsin Central Ry., the work trains are operated under the transportation department, acting under the direction of the roadway department. They receive working orders giving the right to occupy the main line until the arrival of freight and extra trains, but clearing the line of all first-class trains. They are given time when trains are late, allowing them to occupy the main track as long as possible. They are generally required to protect themselves against extra trains, when notified of these by orders. In some cases extra trains must look out for work trains. A telegraph operator is stationed at gravel pits, grade reduction work, etc., to facilitate the movements of traffic and work trains.

On the St. Louis & San Francisco Ry., the trains are under the transportation department, with separate conductors. The roadmaster may arrange with the conductor to do certain work, without the necessity of furnishing a foreman, but the conductor is not held responsible for acting as foreman. When working on main track, as in ditching or distributing material, they are given orders to work within certain limits as to distance and time, with flagmen put out in any case. They must protect themselves against scheduled trains, and either work trains or extra trains may be required to look out for the others. They are given advantage of time when regular trains are late (or are run in sections), if the dispatcher can deliver the necessary orders to the work train. On extensive or important work, and where the traffic is heavy, a telegraph operator is established at a convenient point so as to give the work train all time possible for actual work and to facilitate the movements of regular traffic.

On the Chicago & Northwestern Ry., the work trains are operated by the transportation department, except that on new work (such as track elevation) they are operated by the engineering department. The duties of foreman and conductor are separate, except that in some special cases the conductor acts as foreman in a gravel pit where the forces are light. The trains are governed by telegraph train orders, issued each day, and confined to as short a territory as the work will permit. They must clear the time of scheduled trains, and protect themselves in both directions at all times, when not moving from point to point. Extra trains are not permitted to move in the territory occupied by work trains except by positive meeting orders between them. When scheduled trains are late, work trains are given the benefit of the time as far as possible. No distinction is made between districts controlled by manual or automatic block system and districts not so controlled. On double-track districts where work is extensive, the work trains are sometimes given exclusive use of one of the tracks. In extensive work, such as track elevation, the territory is put under the charge of special train dispatchers. By means of crossovers, trains are moved by special orders, manual and automatic signals. Where a number of work trains or gravel trains are working in and out of a gravel pit,

it is the practice to establish an operator at the gravel pit; also at special points where work is being done, in order to facilitate both the movement of regular traffic and work trains.

Camp and Boarding Trains. — The maintenance-of-way equipment often includes boarding trains for extra gangs, construction gangs and bridge gangs. On the Southern Pacific Ry., the roadmasters have full charge of all track-construction trains; they must lay out their work for them and inspect the boarding and sleeping accommodations. Camp, boarding and other cars used in maintenance-of-way service should be in good condition, well painted, and kept clean and neat. When such cars or trains are to be stationed at one point for any time they are set out on sidetracks, which should be surfaced so that the cars will stand level. The ground around the trains must be kept neat and in condition as at buildings and yards. The cars are usually old box cars, but the Atchison, Topeka & Santa Fé Ry. has used special cars 50 ft. long. The bunk or sleeping cars have six berths (upper and lower) on each side, accommodating 24 men; the berths are 6½ ft. long inside. At the middle of the car is a 10-ft. space with side doors, stove, seats, coal bunker and water barrel. The foreman's car is similar, but with only four bunks on each side, and the same central space. The end of the car is partitioned off, and has a stove, table, and upper and lower berths for the foreman and assistant foreman. One car has half its length devoted to the kitchen. Along the middle of the other end is a table 16×3 ft., with side benches; in the corners are upper berths for the cooks. The dining car has two tables 21×3 ft.

CHAPTER 27.—HANDLING AND CLEARING SNOW.

Many railways encounter difficulties in dealing with snow, and keeping the road open during the winter. If a road is carried on an embankment, even a low one, the snow will drift up on the windward side until it is level with the track, and will then blow over and form a drift on the other side, so that it is not difficult to keep the track clear. For this reason, even prairie lines should not be built on the surface level, but should be raised on embankments. Cuts will soon fill if the wind is blowing across them, unless snow fences are built (Chapter 8). In deep cuts there will be trouble in getting rid of the snow, and all cuts may be made less troublesome by widening them and flattening the slopes. In sidehill work, the drifts against the bank are likely to be dangerous, especially if the toe is about even with the outer rail, as the side pressure on the plow may cause derailment. Drifts and slides containing earth or sand are very heavy and dangerous. Steady falls of light soft snow at a mild temperature are the easiest to deal with if the road has proper equipment, but if the temperature is very low the snow may settle and freeze into a mass, or if the wind is high it may be packed very hard in the drifts. Hard dry snow, whether drifting or packed, is apt to be troublesome by filling up against the rail heads, increasing the liability of the engine wheels to slip and even causing derailment unless flangers are promptly used. The same trouble, but of greater extent, results from partial thaw followed by freezing, which causes the formation of solid ice on the roadbed. The worst drifts are formed by heavy falls of dry, hard snow which will form drifts in every place

affording a lee side. Where the wind blows through a cut the snow will not drift, and in fact a change of wind may clear a cut in which the snow is not packed hard. The weight of snow varies from 12 to 25 lbs. per cu. ft., according to its condition, while the heavy masses in snowslides sometimes weigh as much as 45 lbs. The weight in Canada has been given as follows: Freshly fallen snow, 14¼ lbs. per cu. ft.; 24 hours after falling, 8° F., 21¼ lbs.; 72 hours, 30° F., 28.7 lbs. After high winds, which pack it hard, it will weigh about 30 lbs. per cu. ft. If the snow in drifts 3 to 7 ft. deep has been partly thawed and refrozen and become very hard packed, the plows may ride upon it and be derailed.

Snowsheds are sometimes built in open flat country, but mainly on sidehill lines and to cover deep cuts on mountain divisions, at places where snowslides or deep drifts occur. They are usually heavy log structures, sometimes with rock-filled cribbing on the uphill side, earth being filled in behind the cribbing

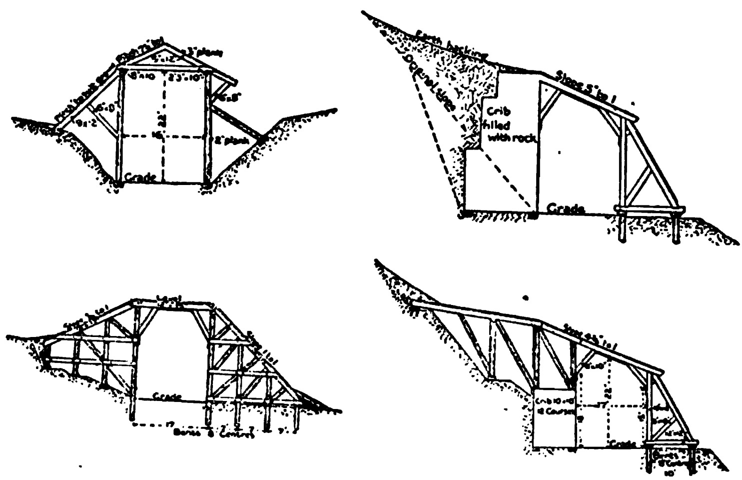


Fig. 222.—Snowsheds; Canadian Pacific Ry.

to form an even slope from the hillside to the outer edge of the shed. Triangular bents are often used for the downhill side, with planking spiked to the batter posts; an opening for light and air is left under the overhang of the roof. The bents are 5 to 10 ft. apart, with timbers 8×10 to 12×12 ins., and 3-in. and 4-in. planking. Some forms of snowsheds used on the Canadian Pacific Ry. are shown in Fig. 222. A line may be laid outside the snowsheds for use in summer. On hillsides where snowslides occur, glance and split fences are sometimes used to guide the snow into gullies and to break up the slide. The latter are V-shaped, with a sharp angle and a strongly braced and anchored crib at the point. They are used to protect the roof openings which allow the smoke to escape. The sheds must be carefully watched and patrolled, as there is great danger from fire, which, if once well started, is very hard to fight. On the Central Pacific Ry., fire trains, equipped with tanks, pumps, hose, etc., are kept in readiness at sidings in the sheds. Some of the large sheds on the Canadian Pacific Ry. have pipe lines, with 200-ft. coils of hose at hydrant nozzles 400 ft. apart.

In fighting snow there are two methods to be followed. The first is defensive, consisting in the erection of snow fences and sheds, and the use of pilot or engine plows or plows hauled by the trains, so as to keep the snow from covering the track to such a depth as to interfere with the traffic. Shallow drifts across the rails, which cause trains to lose time, or necessitate reducing the number of cars, may be successfully dealt with by pilot plows and flangers on the engines, or on cars attached to the trains. The second method is aggressive, and consists in the use of breaking plows and armies of shovelers to clear deep drifts and heavy falls which threaten to blockade or have blockaded the road. In a heavy storm or a succession of storms, the main thing is to keep on breaking up the drifts by snow plows, so that they do not have time to pack and become so hard as to require shoveling. The work of the breaking plow must be supplemented by the wing plow and flanger to widen the cuts and clear the rails. A deep snow-cut with vertical sides, as left by the plow, is liable to fill very quickly. It is wise to break down the sides, shoveling the loose snow into the cut, and then running a wing plow through at high speed to fling the snow to a distance.

In deep drifts, it is well to cut transverse trenches. These may be large trenches, 30 ft. long and 10 ft. wide, and about 30 ft. apart; or short ones, with two men to each trench, the trenches being just as long as the men can work, and 15 ft. apart. This work can be done by the section gangs as well as the snow-shoveling gangs, and facilitates the work of the plow. When men are engaged on this sort of work, or in a narrow snow-cut with vertical sides, a man should be posted on top of the cut to give warning of the approach of trains or plows. The shoveling of snow by hand is slow and laborious work, especially in heavy drifts and with snow falling or fierce winds blowing. Such work is often attended with danger, and the officers in charge should see that the laborers sent out are warmly clad, and that provisions and hot coffee are provided. In shoveling from deep cuts, the work must be done in benches, the vertical height of which is the height to which the men can shovel the snow without too much exertion. With shoveling in heavy work there is sometimes difficulty in getting rid of the material, and it has to be carried out on work trains, and dumped over trestles, etc. In one case on the Canadian Pacific Ry., after several small structures had been filled, the snow trains had to be run considerable distances, entailing great loss of time and constant trouble in backing over track covered with snow due to the almost continuous snowfall and drifts. These difficulties were avoided afterwards by the use of a rotary plow and wing plow, with a small gang of shovelers. The compressed snow on the slope was shoveled onto the track to a width covered by the scoop of the rotary and the wings of the wing plow, and was thus thrown clear of the track, and a good flangeway left. In heavy level snowfalls of over 12 ins., the rotary plow was used, but with less than that the ordinary wing plow was used, as it could be run faster, and time was of first importance, besides which the wing plow cost considerably less in operation. Cuts widened in this way are less liable to fill up again very quickly. Some roads slope the snow-cut back for 30 or 50 ft., and the wider the cut, the longer it will stay open.

The use of plows should be commenced as soon as a storm begins, pilot plows being used first to clear light drifts. For heavy work, the snow is first broken up by a plow driven into it by two or more engines, and when

a passage has been made, the cut is widened by running a plow through it with wings extended. These wings are hinged to each side of the plow, and can extend about 3 ft., their spread being controlled by a man in the "lookout" in accordance with whistle signals from the leading engine. They are, of course, closed in to clear bridges, tunnels, etc. On lines with two or more tracks, an engine with a wedge-shaped, square-nosed plow in front and a wing plow behind may be run on one track, throwing a bank of snow over towards the next track. Following this on the other track is an engine with a side-delivery plow in front and a wing plow behind, with the wing on the outer side of the track extended. This will not only clear its own track but clear off the snow thrown out by the wing of the first wing plow.

Flangers and Flanging Cars.—An important auxiliary to the snow plow is the flanger, which clears the snow and ice away from the rail heads, especially on the inner side, so as to leave an ample flangeway (usually about 5 ins. wide) for the wheels. This device is usually mounted on the snow plow, but sometimes it is fitted to a special flanging car, and operated by hand levers

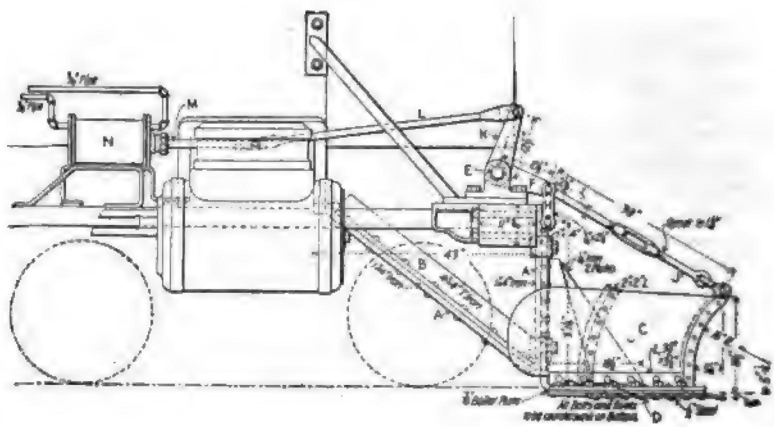


Fig. 223.—Pilot Snow Plow and Flanger.

or air cylinders, it being necessarily raised at frogs, switches and crossings, and at road crossings where the planks have not been removed. A flanger may also be fitted to the locomotive pilot or truck, and one form is shown in Fig. 223. The Priest flanger is placed behind the pilot, the thrust being borne by the truck axle boxes; slotted connections keep the flanger clear of the vertical motion of the engine on its springs. This insures an even depth of cut, however rough the track may be. The bar being but little in advance of the axle, the lateral motion is not much greater than that of the wheels, so that good work can be done on sharp curves as well as on tangents, and without touching the rail. The cutters may be set to within $\frac{3}{4}$-in. above the rail and $1\frac{1}{2}$ ins. to $2\frac{1}{2}$ ins. clear of each side of the rail head, the snow being unable to remain on top and against the rail head after the removal of this backing. With this clearance they will not disturb torpedoes on the rail. This flanger cuts 12 ins. wide inside and outside of rail, $1\frac{3}{4}$ ins. deep inside and $\frac{1}{2}$-in. deep outside. The knives alone are liable to injury, and these are easily renewed. The flanger is raised by an air cylinder. A handy device

for dealing with moderate depths of snow on side or main tracks is a flat car fitted with a nose plow and flangers, the car being well weighted (especially at the ends) by car wheels or stone. It has rigid-center trucks. A car of this kind on the Pennsylvania Lines has a fixed nose 7 ft. 2 ins. wide at the heel, 5 ft. long on the center line, with an angle of about 80°. It is 2 ft. 4 ins. high, and faced with iron like a pilot plow. Between the trucks is hung the flanger, which resembles the plow but has an angle of 60°. This is hung on the end of two 10×5-in. timbers 14 ft. 8 ins. long, set on edge; they form a V, the nose of which is inside the point of the flanger, while the ends butt against the transom in front of the rear truck and are hinged by straps to the intermediate sills. The flanger moves vertically in guides, and is raised by a 10-in. air cylinder.

Pilot and Engine Plows.—The use of the pilot plow, or snow plow bolted to the engine pilot, is common on most railways which have to deal with moderate or heavy snowfalls. They serve to keep the track from getting blocked with snow, except in case of very heavy storms or drifts, and enable the trains to make better time by clearing the track of light snow. In general these are curved plates rigidly bolted to the pilot, but Fig. 223 shows an adjustable plow, operated by air from the brake reservoir, which has been used on the Grand Rapids & Indiana Ry. Four flat bars, A, are bolted to the bumper beam, and carried down to within 3 ins. of the rail level, being then bent back and inclined upward to have the rear ends attached to the cylinder casting. The inclined part is stiffened by a tee iron, B. The plow, C, is of the usual form, with overhanging nose and curved wings, 18½ ins. high above the rail. The sides and bottom are stiffened by angle irons. On each side of the bottom is bolted an ice-cutter or flanger, D, consisting of a ½-in. steel plate with notched edges. When in position for work, this ice cutter is 3½ ins. below the top of the rail. On the bumper beam are bearings for a shaft, E, carrying two arms, F, connected by a cross rod. To this rod are hung two links, H, by which the heel of the plow is lifted, sliding vertically on the bars, A. The diagonal rod, J, lifts the nose of the plow. An upright rocker arm, K, has a connecting rod, L, to the piston rod, M, of an air cylinder, N.

The larger engine plows are usually of iron, bolted to a special frame which takes the place of the pilot, the plow extending above the top of the boiler and being braced to the frame and smokebox. The Northern Pacific Ry. handled snowdrifts up to 4 ft. deep with pilot plows; if they were very hard, channels were cut across the track. The engine plows were of the wedge type. One design had central deflecting wings to throw the snow to each side; the other had a single wing placed diagonally on the wedge portion of the plow and throwing the snow to one side. This was adjustable and used on either side at will. On double track, the single-wing plow was found to be most useful. Engine plows of this kind have been used for drifts even up to 15 ft. deep, the drifts having first been cut by cross trenches. Wire brushes should be attached to engine pilots and behind all flangers so as to clean the rail head.

Breaking Plows.—The ordinary form of breaking or driving plow resembles a large box car with an inclined front end, the plow being propelled by locomotives in the rear. If the plow is run at high speed into a drift it has to stand very severe racking and wrenching strains, and not unfrequently leaves the track. If the plow and engines strike a heavy drift the sudden

shock is likely to derail both plow and engines, or to shift the tender tanks; or the plow may run up into the snowdrift. Drifts that have been in place for several days should not be attacked until soundings or some investigations have been made, as alternate thaws and freezing may have caused dangerous pockets of hard ice. The plow will only drive a certain distance into the drift, and must then be dug out to enable the engines to haul it back for another run. One or more of the engines may have to be dug out. The plow should have a clearance of 3 to 5 ins. above the rails and 5½ ins. from fixed structures such as bridge abutments, tunnel walls, freight platforms, etc. The plow is sometimes curved outward at the top, so as to have a long C-shaped overhang above the lower part; the under side of the overhang slopes upward and backward from the center line. This throws the snow to each side, and prevents it from going on the roof of the machine.

The Russell snow plow, shown in Fig. 224, is extensively used. It has very heavy framing and lateral bracing, and is mounted on four-wheel trucks

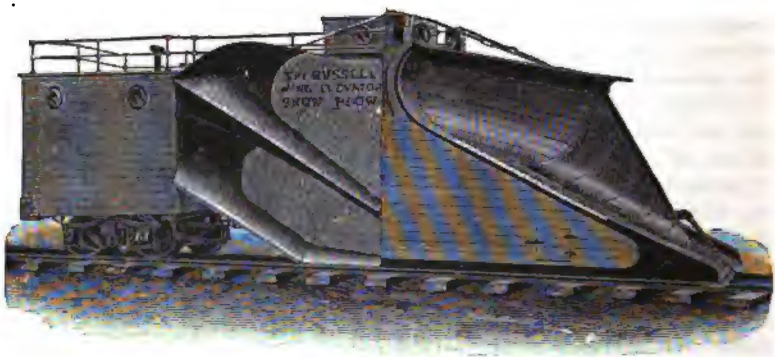


Fig. 224.—The Russell Snow Plow, with Wings.

with roller side bearings. For single track, it has a central nose dividing the inclined plane of the face; for double track, it has a vertical nose at one side, so as to discharge the snow at the side only. The latter plow may also be used for sidehill work. On each side is an elevator wing, 9 × 11 ft., for use in deep drifts, the wings being forced out so as to widen the cut, and having curved channels by which the snow is delivered above the machine. These, with a slight tapering of the sides back from the front, prevent the snow from wedging or binding against the side of the plow. The wings are operated by gearing by means of hand wheels in the car. The pushing beam is formed of two oak timbers bolted together, and the front end is let into the oak timber which forms the backbone of the inclined face of the plow, so that the propelling power is applied right at the nose of the plow. This greatly reduces the danger of derailment. The timber is not a fixed part of the framing, but has a certain lateral play for curves. The horizontal edge of the plow is faced with steel; about 5 ft. back from the edge begins the share, with curved flaring sides to throw off the snow. The sharp cutting edges of the front and sides enable the plow to get into and under the snow, wedging it up and lifting and loosening it before it reaches the share, where the side pressure begins. This tends to reduce liability to derailment. The front end is covered with

$\frac{3}{8}$-in. steel plate, and the double-track plow has on the side opposite the run of the share a $\frac{3}{8}$-in. steel plate extending the full height of the machine, its front edge forming the vertical cutting edge in advance of the share. A man in the cab or outlook signals the engineman of the pushing engine by a bell cord. The plow has successfully attacked hard-packed snow 6 to 12 ft. deep, using two engines, and having a speed of about 30 miles per hour in running at the drifts. After the first cut is opened, the plow is run through with extended wings to widen the cuts and make a slope instead of a vertical wall.

Machine Snow Plows.—The introduction of machine snow plows has rendered the work of keeping lines open and of opening blockaded lines very much easier than when only breaking plows and hand shoveling were available. The Leslie rotary plow has been used on a number of railways. It is a large car mounted on four-wheel trucks and containing an engine and boiler, with gearing to drive a wheel 11$\frac{1}{4}$ ft. diameter which revolves in a vertical plane transverse to the track. The wheel revolves in a circular shell or drum, in front of which is a rectangular housing 12 ft. wide which trims the sides and bottom of the cut. The wheel has 10 or 12 radial hollow scoops of conical shape, each having the front side open and fitted with a knife on each side of this opening. The snow planed off by the knives falls through into the scoops, whose centrifugal action discharges it through a chute in the top of the housing. The discharge is directed to either side, and the snow falls at a distance of 50 to 200 ft., according to the speed of the wheel. Ice cutters are fitted in front of the leading truck, and behind it are the flangers. Each of these devices is held by a shearing bolt, which will break and allow the blade to swing aside if it strikes an obstruction. The discharge chute, ice cutters and flangers are operated by air cylinders, controlled from the cab. The machine is about 30 ft. long, weighing 60 to 100 tons, and has a tender for coal and water. It is usually propelled by one or two powerful engines at a speed of about 6 or 8 miles an hour in snow up to 6 ft. deep, or 5 to 6 miles an hour in snow 10 to 15 ft. deep. It will make a cut 13 ft. 4 ins. wide. It must not make a run at the work, but must be fed forward steadily at such speed as will not result in choking the wheel. The wheel should be stopped in crossing bridges or trestles. A steam hose is provided for thawing out the wheel if it should become frozen.

On the Colorado Midland Ry., the machine has worked through snow 10 ft. deep at 10 miles an hour. The greatest trouble is on account of slides. The plow is driven slowly in until it cannot throw the snow clear; it is then backed out to allow the snow to fall in, when the plow is again forced into the drift. This is repeated until the plow gets through the drift. Rocks and timbers are often encountered in these slides, and are pulled out by chains. In some heavy work on this road, snow 30 to 34 ft. deep was encountered which would have choked the discharge outlet of the plow in a few minutes. The snow was hard and compact, and partly frozen. Lines of men were placed along the slope, each line of men throwing the snow up to the line above, until it was raised to a height varying from 40 to 60 ft., and finally disposed of, leaving not more than 12 ft. of snow in the bottom of the cut. Holes were drilled into this bench of snow, and charges of giant powder were exploded to shatter the frozen bank, after which the men were stationed on the bench of snow immediately in front of the plow to drag the snow down with shovels and throw it in the bottom of the cut in blocks from 1 cu. ft. to 2 cu. yds. in

size. After breaking this snow down, the plow would run into the loose snow, throw it up on the bench excavated on the slope of the cut for men to stand on, and the men would shovel it one to the other again until it could be disposed of over the top of the cut. Each time the plow would run into the shattered snow it would remove that snow and force itself from 5 to 10 ft. into the undisturbed mass of snow. Progress was necessarily slow in such exceptionally difficult work.

The Jull or "cyclone" plow had at the front end of the car a great cone, with its apex at the front lower corner of a housing, and the center of the base at the opposite back upper corner. The cone was of ½-in. steel plate. It was 7 ft. 8 ins. long, 1 ft. diameter at the apex and 7½ ft. at the base. Riveted upon it were four spiral curved cutting blades, making about 75% of a revolution in the length of the cone, and varying in height from 16 ins. at the axis to 24 ins. at the base. They were made of two thicknesses of ⅜-in. steel plate, pressed to shape in dies. At the front they were nearly straight, but towards the base their curve increased gradually. They were cut away at the base for a width of 24 ins. on the cone, to allow the snow to escape freely. The housing was 10 ft. 4 ins. wide, 9 ft. 4 ins. long, and about 9 ft. deep, the bottom being 3½ ins. above the rail head. The cone was driven at about 350 revolutions per minute by the engine. The blades carried the snow to the base of the cone, where it was discharged by centrifugal force through a chute in the housing, and fell at a distance of 40 to 60 ft. from the track. These machines have been used on the Union Pacific Ry. to a limited extent.

Yards and Switches.—The section men and yard men must look to the clearing of snow from yards, switches, frogs, crossings, guard rails, and interlocking work. Extra gangs will often be required in heavy storms, especially at passenger terminals. Yards should have plenty of good clean ballast, and be kept well drained, so that after a thaw there will be less liability of freezing up the switches. The trenches in which switch connecting rods work should be kept open to prevent the accumulation of water. Salt should be used in clearing snow and ice from switches and frogs, and light drifting snow must be swept out frequently. The slide plates must be kept oiled, as the salt water will rust the iron and make the switch rails hard to move. Where many snowstorms occur during the winter it is a good plan to put up posts near the switches in yards, with a broom and shovel hung on each ready for use by trainmen or switchmen. Hard ice and packed snow usually have to be cleared by hand to give proper flangeways, but the Boston & Maine Ry. has a special car for this purpose. A heavy cutter blade breaks up the ice, and a scraper blade or flanger behind cleans away the loose ice. The blades can be raised and lowered by levers or air cylinders. A track sweeper with revolving brooms (as used on street railways) has been used in some large yards. Weed-burning machines may also be used in clearing yards and interlocking plants. The Boston & Maine Ry. has experimented with oil and gas heaters placed at the switches in a busy passenger yard, and connected with a pipe system. The snow is melted as it falls, so that there is no large accumulation to cause trouble with the switches or in its removal. The system keeps the ground warm, so that it is not frozen and can absorb the melted snow.

Electric Railways.—On interurban railways, the regular cars may be fitted with pilot plows, scrapers and flangers, and there may be work cars or baggage cars fitted with nose plows and side leveling boards. Large wing plows

of the Russell type are sometimes used, and a few lines have rotary plows for handling deep snow. These are similar in principle to the railway rotary plows already described, but with only four blades on the 8-ft. cutter wheel; this wheel runs at about 450 to 650 revolutions per minute, and behind it is a fan wheel which discharges the snow. To clear trolley wires from sleet, the trolley pole may carry a scraper or a special wheel having ribs or lugs in the groove so as to cut the ice and jar it loose. Where the third-rail conductor is used, the cars are usually equipped with wire brushes or scrapers to clean the head of the rail, and in some cases a small stream of calcium-chloride solution is fed upon the rail in advance of the contact shoe. Tests with the electric locomotives of the New York Central Ry. showed that there is less trouble from sleet when the shoe rides against the bottom of the third rail, the top being covered by a shield. City and suburban cars are very generally equipped with scrapers or flangers, and these should be attached to the truck frame. Track sweepers and spreader cars are also used in streets. Salt is sometimes used at frogs, switches and special work, and on grooved rails. If used too freely it is liable to cause trouble with the electrical apparatus, and it is objected to in some cities as it makes a slushy mixture injurious to public health and affecting the hoofs of horses. On elevated railways, scrapers and wire brushes on the cars (or handled by trackmen) are usually employed to clean the third rail, and sometimes there are special cars with rattan brushes to clear snow from between the guard timbers.

CHAPTER 28.—WRECKING TRAINS AND OPERATIONS.

While careful precautions may be, and should be, taken to insure safety in railway operation, accidents will occur inevitably. These include train accidents (mainly derailments and collisions), washouts of banks and structures by floods, landslides, and the damage or destruction of bridges and trestles by fire or train accidents. Provision must be made for rendering aid, and for reopening communication with the least possible delay to traffic. Wrecking trains with efficient working gangs are therefore an important feature in the operating plant. They are equipped with cranes or derricks, pile drivers, tools and appliances for clearing the track and building temporary tracks or structures. Special provision is also made for the relief of persons injured in the accidents. The trains are stationed at terminal and division points, where locomotives and men are available. In case of train accident, it is of great importance to remove the wreckage and clear the track as quickly as possible. This should not be done by the reckless smashing of cars or other equipment which may, with a little care and clear-headedness, be saved and moved out of the way without additional loss of time. In repair work and temporary structures also, absolute safety is of greater importance than mere rapidity. Forethought, judgment, care and speed must be combined in work of this sort.

The systems of organization are various, but the best plan is to have the roadmaster in direct and supreme control of the work at train wrecks, subject only to the orders of the superintendent (if he is present). The foreman

of the wrecking train will be in charge until the arrival of the roadmaster. The repair of structures or the construction of temporary structures may be in the hands of the superintendent of bridges and buildings, or the bridge foreman, until the arrival of the former. The crew of the wrecking train is usually organized from the shopmen; they are familiar with engine and car work, and with the handling of loads by jacks and tackle, and are competent to handle and repair damaged and derailed equipment. There will be a wrecking foreman (or wreckmaster), an engineman and fireman for the steam crane (who may work in the power house, roundhouse, or shops), and 10 to 20 car-repair men and machinists. There should be telegraph apparatus, and the foreman or one of the men should be able to tap the wires and open communication with headquarters. The Oregon Short Line uses telephones, the apparatus on the car being connected by a 100-ft. wire with a pole which can be hooked over a telegraph wire. One man will have charge of the tool car, another will act as cook and steward. Another man is stationed (during the work) on the front of the wrecking car, where he can see the foreman or roadmaster, and transmit the orders to the engineman. When an accident is reported, the men should be notified by messengers; at night, electric bells or telephones may be used. It is common practice to sound the steam whistle at the shops, but this is objectionable. It causes excitement in the shops, advertises the fact of an accident, and causes anxiety among the relatives and friends of employees. When an accident occurs, the nearest section foreman must collect his gang and at once proceed to the scene, even if it is not on his section. When assisting a train delayed by accident he is usually required to act under the orders of the conductor until the arrival of the roadmaster or wrecking foreman. He must appoint watchmen to protect property and prevent theft. The section forces are of great importance at wrecks, as they have to repair the track or build a temporary line around the wreck, besides helping in the general work. The officers and employees of the different departments must co-operate in the endeavor to have the road open for traffic as soon as possible.

The wrecking train usually consists of a powerful steam crane or derrick car, flat cars with blocking, track material, and spare trucks, a tool car, and a car for the men. The train is always in readiness on a special track that must be kept open, and sometimes there is a train crew always in the caboose. The first locomotive available is ordered to take out the train when needed. The men's car should have sleeping accommodation and facilities for supplying a large gang with food. This is better than relying on eating houses and hotels; the meals are better, the men are better cared for and lose less time, and the arrangement is more convenient in many ways. The car should have a kitchen equipment, hot-water tanks, coffee tank, and such supply of canned goods as may be required in each case. One of the crew should be an efficient cook, and in charge of the supplies. The main part of the car may have berths, benches, table, stove, etc. The tool car should be equipped for the convenient storage of ropes, chains, tools and appliances. It should be in charge of one man. He must see that the equipment is complete and in order for immediate use, and keep the tools in repair. Wet or dirty ropes must be cleaned, thoroughly dried, and then neatly coiled and put in their proper places. He must have a list of the equipment, and immediately after the work is done he must check it over; any tools, etc., lost or damaged must be at once repaired or

replaced. The tools of each wrecking train should be painted or marked in a distinctive manner.

Hydraulic jacks of 10 to 30 tons capacity are important tools, second only to the crane or derrick, and some of them should lift by means of claws (like track jacks). For putting derailed cars or engines back upon the rails, various forms of metal wrecking frogs (or rerailing frogs) are used. One of these is shown in Fig. 225. The frogs are set upon or beside the rails, and in raising the wheels they guide them laterally so as to place them on the rails. The tool car must have an extensive supply of ropes and blocks, wire cables, long and short chains, jacks, common tools, track tools, shovels and scoops, baskets and bags for handling grain, etc. The track material on one of the flat cars will include rails, splice bars, one or two switches, frogs and guard rails; also about 100 ties, 5 kegs of spikes and 2 kegs of bolts. The Southern Pacific Ry. requires that at the headquarters of each roadmaster's division there must be at least 1,000 ft. of rails suitable for temporary tracks, and so placed as to

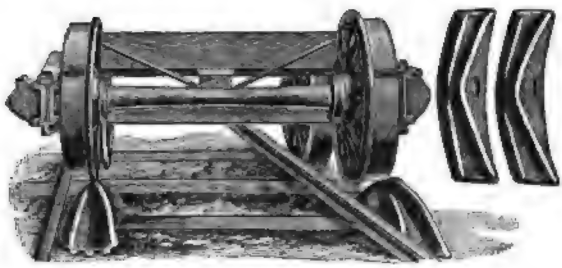


Fig. 225.—Wrecking Frogs or Car Replacers.

be readily loaded on cars. Piles and bridge timbers, as well as ties (for track and cribbing), are also generally available at such points.

The car for the crew may be used for hospital purposes. On one road, this car has 10 berths for the men (or for injured persons), and is equipped with kitchen, hot-water tanks, stretcher, operating table and medical supplies; also instructions for aiding injured persons until medical or surgical aid can be obtained. A few railways have hospital cars. As a rule, arrangements are made with doctors at towns along the line. In case of an accident involving a number of injuries a special train is sent out as soon as possible with doctors, nurses and supplies. For the care and transportation of injured persons, an ordinary car is better than a parlor or sleeping car, owing to the winding entrances of the latter. Stretchers may be placed across two reversed seat backs, which gives them about the right height for convenient medical attention. In case of cattle-train wrecks, the uninjured stock should be transferred promptly, and badly injured cattle must usually be killed on the spot. With refrigerator cars, special care should be taken to replace the ice and put scattered freight back in one of the least injured cars.

Efficient lighting is one of the most important features for night work, and little can be done when only hand lamps are available. Electric and acetylene lamps are sometimes placed on the boom or A-frame of the wrecking crane, and the Erie Ry. has used a revolving headlight on the roof of the wrecking car. The acetylene system has been used on the Union Pacific Ry. and the Lake Shore & Michigan Southern Ry. The Lehigh Valley Ry. has a too

ern Pacific Ry. for such work, the dimensions of the lettered parts being given in Table No. 39.

TABLE NO. 39.—LAYING OUT TEMPORARY TRACKS AROUND WRECKS AND WASHOUTS; SOUTHERN PACIFIC RY.

A, ft.	B, ft.	C, ft.	D, ft.	E, ft.	F, ft.
		Ten-Degree Curves.			
10	53.6	103.3	156.9	2.5	7.5
20	84.0	133.5	217.5	6.3	13.7
30	107.3	156.5	263.8	10.3	19.7
40	127.3	176.0	303.3	14.4	25.6
50	144.8	193.1	337.9	18.7	31.3
60	160.3	208.3	368.6	23.0	37.0
70	174.5	222.1	396.6	27.4	42.6
80	187.8	235.0	422.8	31.8	48.2
90	200.2	247.0	447.2	36.2	53.8
100	211.9	258.3	470.2	40.7	59.3
		Fifteen-Degree Curves.			
10	42.2	92.0	134.2	2.3	7.7
20	66.2	115.4	181.6	5.7	14.3
30	85.0	133.7	218.7	9.5	20.5
40	100.8	149.2	250.0	13.5	26.5
50	114.7	162.6	277.3	17.5	32.5
60	127.2	174.4	301.6	21.5	38.3
70	138.7	185.6	324.3	26.0	44.0
80	149.4	195.6	345.0	30.3	49.7
90	159.2	204.8	364.0	34.6	55.4
100	168.5	213.5	382.0	39.0	61.0

Chicago & Northwestern Ry.—The wrecking train kept at the Chicago shops consists of a 100-ton steam wrecking crane, a flat car for blocking, chains, equalizers, etc., a box car for jacks, ropes and sheave blocks, one car equipped with bunks and cooking outfit for the wrecking crew, and one car or caboose for the train crew. The wrecking crew consists of the foreman, engineman,

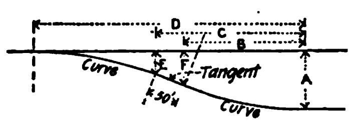


Fig. 227.—Diagram of Temporary Track for Passing Around a Wreck; So. Pac. Ry.

fireman and two handy men, who are employed in the roundhouse; also two car repairers, who are employed in the adjacent repair yard. The section gang or gangs nearest to the wreck are also used. It takes about 15 mins. by day, or 30 mins. at night, to get the train started.

Pennsylvania Ry.—The wrecking train stationed at Altoona, which may be taken as representative of the main-line practice, is composed of locomotive and tender, 70-ton steam crane, low-side gondola car (carrying trucks, coal buckets, cables, etc.), tool car and commissary car. An extra tool car is kept ready for emergencies during the absence of the regular train. The list in Table No. 40 gives in detail the equipment of the wrecking train. It is also equipped with the Wells light for night work. In addition to the train crew, the wrecking crew is composed of the wreck master, derrick engineman, two men in immediate charge of the tool and commissary cars and all tools, and about 35 men who are called from the shops when needed. The supervisor is present at all wrecks of any importance. The work at wrecks is in charge of the wreck master, subject to the direction of the supervisor.

TABLE NO. 40.—EQUIPMENT OF WRECKING TRAIN; PENNSYLVANIA RY.

Blocking: (60 pieces) 6×6×6 ins.; (75) 6×6×48 ins.; (300) 2×12×18 ins.
Anchor blocks: (30) 5×10×36 ins.
Wedges (hickory): (300) 3½×4×24 ins., tapered.
Manila tank ropes, each with a hook and link:
(6) 2-in., 30 ft.; (2) 2-in., 60 ft.; (3) 3½-in., 30 ft.; (2) 3½-in., 60 ft.; (1) 3½-in., 80 ft.; (1) 3-in., 150 ft.; (1) 3½-in., 200 ft.
Manila 2-in. rope, without hook or link: (1) 100 ft.
Manila 2-in. rope slings: (2) 3 ft.; (2) 2 ft. 10 ins.; (2) 2 ft. 8 ins.; (1) 1 ft. 6 ins.; (1) 1 ft. 4 ins.
Manila 1¾-in. rope for block and fall: 600 ft.
Block and fall: 3 sets.
Wire cables, with link and hook: (2) 1¼-in., 11 ft.; (1) 1¼-in., 60 ft.; (1) 1⅝-in., 9½ ft.; (1) 1⅝-in., 18½ ft.; (1) 1⅝-in., 25 ft.
With link at each end: (2) 1-in., 36 ft.; (1) 1⅝-in., 27 ft.
With hook and eye: (2) 1¼-in., 9½ ft.; (2) 1¼-in., 5 ft. 2 ins.
With link in middle and hook at each end: (2) 1-in., 7 ft. 2 ins.; (2) 1-in., 12 ft. 3 ins.
Log chains: (50) 1-in., 17 ft., with hook and link; (6) 1-in., 5 ft. and (6) 1-in., 6 ft., with hook at each end; (16) ⅝-in., 9½ ft., with one hook.
Double-lift chains (4): flat hook at each end, and ring 1½×8 ins.
Chain slings: (1) 1-in., 3½ ft.; (1) 1¼-in., 4 ft.
Stone-lift chain: (1) ⅝-in., 19½ ft., with link 18 ins. from one end and a hook on each end.
Chains: (2) ⅝-in., 9 ft. and (4) ½-in., 3 ft., with one hook; (4) 1½-in., 8 ft., with hook on each end.
Pulling bars: (2) 6 ft. long, (2) 4 ft., (2) 1½ ft.
Jacks, short: (3) 15-ton, (2) 20-ton; medium: (1) 15-ton, (2) 10-ton, (2) 20-ton; long: (3) 15-ton, (2) 20-ton.
Shovels: (8) clay; (10) long-handled scoops; (75) short-handled scoops.

15 Fire buckets.
Fire hose, 150 ft.
6 Fire hooks (4 with attachments).
3 Snatch blocks.
2 Grappling irons.
6 Fulcrums.
6 Levers.
1 Track gage.
1 Wheel and axle gage.
1 Wheel gage.
1 Coil telegraph wire.
1 Coil copper wire.
1 Reel insulated wire.
2 Pairs telegraph climbers.
2 Vises for splicing wire.
2 Pairs pliers.
1 Telegraph instrument with relay.
1 Telephone instrument with relay.
1 Portable telegraph office.
1 Desk.
2 Wooden mallets.
35 Coupling pins.
6 Coupling links.
50 Key center pins 15-in. and 17½-in.
12 Head center pins 26-in.
6 Draft pins.
200 lbs. rail spikes.
7 Sets patent frogs.
6 Pinch bars.
2 Claw bars.
4 Spike hammers.
12 Sledges.
8 Jack braces.
8 Long jack hooks.
2 Short jack hooks.
11 Augers (1 each), 2-in., 1¾-in., 1½-in., 1¼-in., ⅞-in., ¾-in., ⅝-in., ½-in., ⅜-in.; (2) 1-in.
2 Hand saws.
2 Cross-cut saws.
1 Hand axe.
3 Pole axes.
4 Soft hammers.
8 Iron hammers.
4 Large and 6 small monkey wrenches.

2 Carpenters' chisels: (1) 2-in., (1) ¾-in.
1 Gouge chisel.
18 Chipping chisels.
6 Files, 14-in.
3 Sponge hooks.
6 Coke forks.
6 Picks.
18 Cold cutters.
3 Wrecking trucks (100,000 lbs.).
3 Push poles.
2 Patent coal buckets.
24 Coupler knuckles.
2 Couplers.
1 Large lift beam.
1 Rail lift.
2 Sets stone hooks.
4 Side-lifting hooks.
3 Center plates.
1 Rear-end engine lift.
1 Yoke lift.
24 Brakeshoes.
18 Journal bearings.
18 Journal wedges.
60 Knuckle pins.
6 Cutting bars.
1 Pair body pin tongs.
2 Pairs backing tongs.
12 Truss-rod wrenches.
4 Sets cup wrenches.
36 S-wrenches.
5 Patent pulling hooks.
12 Steel backers.
4 Locking-pin backers.
12 Air hose and fittings.
6 Angle cocks.
12 Air-hose reducers.
1 Syphon hose.
2 Sections hydrant hose (50 ft. each).
32 Washers for frogs.
6 Sets clamps for frogs.
12 Keys for frogs.
3 Diamond cutters with handles.
3 Diamond cutters without handles.
2 Sets sheet-steel hook lifts.
2 Pulling jacks with hooks and chains.

2 Portable Wells lights.
4 Extra Wells lights' burners.
2 Extra Wells lights' hoods.
1 Oil tank (60 gals.)
4 Tarpaulins.
1 Closet.
3 Sponge buckets (filled).
6 Cant hooks.
1 Set loose iron blocks for replacing tires on engines.
1 Patent lever for lifting locking pins.
1 Post-hole digger.
6 Hay hooks.
1 Box tong.
3 Pipe cutters.
1 Hack saw.
12 Sets rope or cable clamps.
200 lbs. bolts and nuts.
50 lbs. nails.
1 Set rope splicing tools.
1 Rail clamp.
24 Duck suits.
2 Single-bracket lamps.
1 Four-bracket lamp.
1 Ice box, 500 lbs. capacity.
1 Water tank, 60 gals.
1 Cooking stove (Acorn).
3 Heating stoves.
6 Brooms.
2 Dusting brushes.
12 Oil cans.
100 Three-bushel bags.
10 lbs. waste.
4 Fire shovels.
200 Signal caps.
2 Sets flags (green).
2 Sets flags (red).
4 Side lamps.
18 Torches.
1 Stretcher.
2 Boxes first aid to the injured.
Lamps: (4) red, (12) white, (2) blue.

Washouts and Burnouts.

In times of continuous heavy rain, floods and freshets, or in protracted droughts, when there is danger from fire, precautionary measures should be taken by keeping fire tubs and buckets full, clearing snow and drift from all waterways, and by putting on extra watchmen and trackwalkers to look after the safety of structures and watch for indications of undermining of foundations, slips in cuts and washouts in banks. During such times the section foremen and roadmasters should keep the superintendent informed as to the condition of the road. This will prevent delay in running trains cautiously where the road is perfectly safe, and will insure prompt attention to any point of danger. After a flood has subsided, an examination should be made of the foundations of abutments, piers, trestle bents, etc., as a precaution against undermining. Damage to falseworks, temporary trestles, etc., by drift and logs, may be prevented by a boom of logs on each side of the stream, with the upper end of the boom attached to the shore. These will guide floating objects through the waterway. Men may be stationed to guide them through by means of poles, so as to prevent any obstruction. Ice jams or gorges may be shattered and broken up by explosives. A charge of about 100 lbs. of blasting powder in a 4-gallon can is sunk through a hole into the water, and allowed to drift some distance under the ice, being held in position by a rope tied to a stake at the hole. The charge should be exploded by an electric blasting battery, and not by a time fuse.

In case of a washout, burnout, wrecked structure, caved-in tunnel, etc., the foreman should first take steps to send out flagmen to stop trains, and then report at once to the proper track official and the superintendent, stating in full the exact location of the accident, the number or name of structure, character and extent of damage, etc., and particulars of train wreck (if any). He should then do what he can with the means at his disposal to prevent further damage, and prepare for the repair work. The pile-driver train and bridge gang will then be sent out promptly, equipped with the necessary plant and tools. Further cutting away of the banks of a washout may be checked by covering them with stone, logs, or brush and trees interlaced to form a mattress, or even by rough cribbing to cut off destructive currents or eddies. It is generally useless to try and fill a gap with anything but stone if a current is flowing through it. If the water is too high or turbulent to allow of commencing the repair work at once, the time may be spent in collecting material, building trestle bents, cribs, etc., and filling sacks with earth.

A pile driver is a very important machine where large washouts of banks or repairs of trestles or bridges have to be dealt with. Steam shovels can be used to advantage at landslides. Railway pile drivers are heavily built flat cars, with leaders carried by a frame supported by a turntable on the deck of the car In some designs, the turntable is at the middle of the car, with the engine and boiler at the rear end of the frame to counterbalance the leaders. In others the engine and boiler are stationary in a cabin at the rear end of the car with the turntable at the front end. The frame has a travel of 16 to 20 ft. over the turntable to allow of setting piles a panel length ahead of the car, and 10 to 20 ft. on either side of the center of the track. The leaders should be 40 or 50 ft. long, and adjustable for driving batter piles. The machine should be able to work in a through bridge, so as to drive piles for falsework

for renewal or repairs. The leaders are usually pivoted about 12 ft. above the rail, so that when lowered for transportation the upper end rests on the engine-house roof, while the lower ends project in front of the car. This makes it necessary to put a flat car ahead to enable the pile driver to be coupled into a train, or the machine may have a tender or pilot car. One end of this is like a flat car, to pass under the leaders, the other end is like a box car and used for tools and supplies. The leaders sometimes fold together upon the car, or roll backwards and downwards on a curved heel, so that when lowered they do not project beyond the car. A pipe and hose for water jet may be added to the equipment, and some pile drivers carry a steam-pile hammer as well as the usual 3,000-lb. drop hammer. There may also be a boom for handling piles and placing caps and stringers.

An engine of 25 or 30 HP. will operate the pile driver, hoists and propelling gear. The machine should be self-propelling (at 6 to 10 miles an hour), as when at work it can be handled more readily by its own power than by a loco-

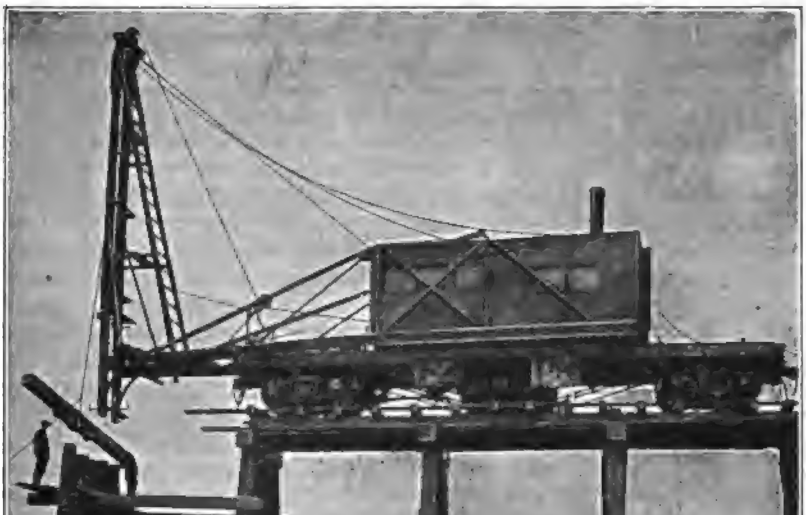


Fig. 228.—Railway Pile-Driver Car.

motive. In one design, the car is of plate-girder construction, and the turntable is mounted on a traveling frame which can be moved along the deck of the car. The turntable carries a pair of trusses, with the leaders at one end and the machinery at the other; the leaders are raised and lowered by a power-operated strut, and are adjusted to drive batter piles. When the leaders are lowered and the turntable is at the middle of the car, no part projects beyond the end sills. The engine has cylinders 9×12 ins. The machine has a chain drive for self-propulsion, the chain being disconnected while the machine is being hauled by a locomotive. The turntable can be revolved 360° in either direction, and the machine can drive piles 20 ft. in advance of the car or 23 ft. from the center of the track. A railway pile driver is shown in Fig. 228,

and a number of designs are described in the Proceedings of the Association of Railway Superintendents of Bridges and Buildings, 1902. The pile-driver train should be in charge of a bridge foreman, acting also as conductor. When at work on renewals and repairs he must notify the train dispatcher, and put out flagmen.

A pile-driver car used on the Missouri Pacific Ry. is 55 ft. long, and the leaders can be carried 16 ft. ahead of the car body, so as to build 15-ft. panels. It has a reach of 14 ft. on either side. The leaders are 40 ft. long. A 3,000-lb. hammer is used. The pile handling and hammer lines are led over different sheaves on the leaders and over guide pulleys back to separate drums on the engine, which has two cylinders 7½ × 10 ins. and two 12-in. drums. Steam is supplied by a vertical boiler. The car is fitted with two 1½-in. manila hammer lines, and two 1¼-in. pile lines having one end spliced to the ring of a ½-in. crane

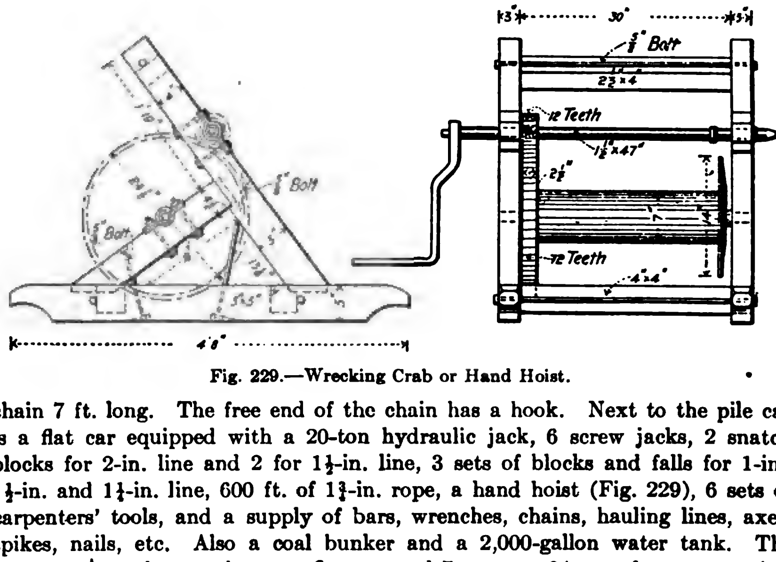


Fig. 229.—Wrecking Crab or Hand Hoist.

chain 7 ft. long. The free end of the chain has a hook. Next to the pile car is a flat car equipped with a 20-ton hydraulic jack, 6 screw jacks, 2 snatch blocks for 2-in. line and 2 for 1½-in. line, 3 sets of blocks and falls for 1-in., 1½-in. and 1¼-in. line, 600 ft. of 1¾-in. rope, a hand hoist (Fig. 229), 6 sets of carpenters' tools, and a supply of bars, wrenches, chains, hauling lines, axes, spikes, nails, etc. Also a coal bunker and a 2,000-gallon water tank. The crew consists of an engineman, fireman and 7 men, or 24 men for emergencies; 8 of these are laborers and the others bridge men. In 10 hours, this crew could drive 5 bents of 4 piles each, cut them off, and fit caps, stringers, ties and track. Fig. 230 shows a derrick car which can be used as a pile driver, having the leads suspended from the boom and held at the bottom by a brace run out from the deck of the car. The A-frame is fixed, and is short enough to allow the machine to work in through bridges. In many cases, however, the A-frame is lofty, and is pivoted to swing back to an inclined position for transportation. Derrick cars of this latter type on the Illinois Central Ry. can drive piles for three bents (14 ft. c. to c.) in advance of the machine. Derrick cars are used in construction, bridge erection and repair work. (See "Bridge Work," Chapter 25.)

If a temporary trestle is required, piles may be driven, cut off to height and connected by caps drift-bolted in the usual way. If a pile driver is not available, a hand derrick or a gin pole (or shear pole) may be used to handle piles, timbers or framed bents. Two piles may be "jumped" and churned by means of ropes to sink them into the bed, and secured to each other by

plank braces as soon as they are in place. The planks serve to guide the additional piles. In this latter method, it is less necessary to get the piles evenly spaced than to locate them in holes and soft places. Another method, which may be used where there is hard bottom, is to make soundings for each leg of the bent, cut the posts to length, connect them by a drift-bolted cap, and a 3×10-in. diagonal brace and 4×10-in. horizontal plank at what will be the water line. The bents are then placed in position and connected by longitudinal bracing. With a rocky bottom and a swift current, holes may be drilled and light charges of dynamite used to make holes to receive the large ends of the piles. On each batter pile is bolted a block 12×12×36 ins., with a 2-in. gas-pipe sleeve; through this a hole is drilled in the rock for a 1½-in. anchor bolt. If the channel is wide, rafts or boats may be used, being held in place by lines. From these, men guide the piles into the best position that can be found, and put in a horizontal cross brace (two 3×10-in. planks) at

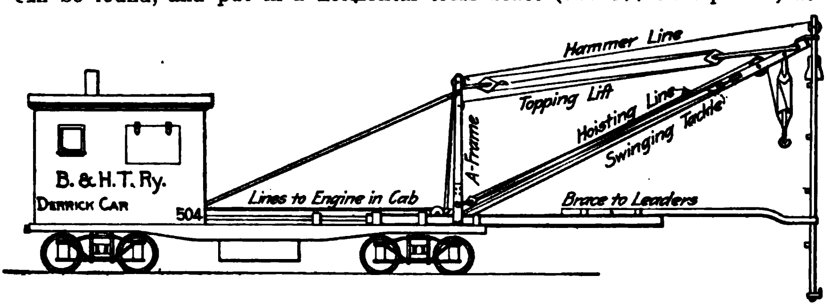


Fig. 230.—Derrick Car and Pile Driver.

the water line. The top gang puts on a similar top brace or ledger board (one plank 2×10 ins.) below the level for the caps. For 16-ft. panels, 4 or 6 posts may be used, with 32-ft. joists or round timbers. These joists are run out over the ledger boards, with the heel chained to one bent, and the other end projecting 16 ft. beyond the last bent. A few planks are laid on these for the men to carry out the posts for the next bent. Sighting over the ledger boards gives the level for cutting off the posts for the caps, which are secured to them by drift bolts or spiked batten planks. After the caps are set, the ledger boards are removed and diagonal sway braces put across the bent. The bents are connected by horizontal sash braces or girts, with diagonal bracing in the end panels.

In many cases, bents are framed on shore and floated out, being then raised and set in place by a derrick or by lines from a pile driver or shear pole. For a washout, heavy bents may be used, with double sills and caps, the posts being well braced. At each end of the sill is a 2½-in. hole with a gas-pipe sleeve extending above the water for use in drilling a hole for an anchor bolt. The bent may be weighted by pig iron, stone, splice bars, etc., attached to the sill; or pieces of rail may be spiked vertically to the lower ends of the posts. A box for the weights may be formed by planking up each side of the bent for about 3 ft. at the bottom. Fig. 231 shows a four-post bent with a double cap to which only the batter posts are bolted, the vertical posts being secured by lashing. The lower ends are held in place between the sill planks by blocking, so that when the bent is in place, the posts can be tapped down to a full bearing. The posts are then sawed off, the top brace or temporary cap

removed, and diagonal bracing put on. The cap is then placed and drift-bolted, and stringers are put in place for the ties. The Southern Pacific Ry. has used rods for diagonal bracing in high bents. Stone may be filled around the bents to prevent undermining. On the shore and in shallow water old ties may be used to form a seat for the sills of the bents. Those farther out may be set on heaps of broken stone dumped in place and leveled off.

The timbers should not be put together with mortise and tenon joints; this work is expensive, takes time, and prevents the subsequent use of the timber in other work. The timbers should be butted together, bored and bolted, or secured by plank battens or splices spiked on. A handy method of fastening timbers is to use dog irons 12 ins. long, with the ends bent for 4 ins. to drive into the two pieces; the ends are chisel-pointed, one vertically and the other horizontally. One leg is at right angles to the 12-in. side, the

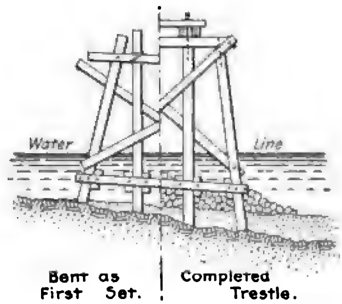


Fig. 231.—Setting Framed Bent for Trestle at Washout.

other at a little more than a right angle, so as to pull the timbers together. Two dog irons should be driven simultaneously on opposite sides of the joint, so as not to displace the timbers in driving. Spikes should be ½-in. boat spikes, 8 ins. long. The middle posts are usually 5 ft. c. to c. The caps will be about 10 ft. long for four-post bents with batter posts, or 14 to 16 ft. if all the posts are vertical. The stringers should be built up of two or three pieces (breaking joints) and may be secured in place by triangular blocks spiked to the caps and stringers.

Cribs built of old bridge timbers, logs or ties may be used instead of bents. Cribs of ties will be about 8×8 ft. with from two to four ties in each course, and a single crib of this kind will suffice for a height of 6 to 8 ft. For a greater height, there should be two cribs side by side, or a wider crib with the two rows of ties transverse to the track, these ties overlapping side by side. The cribs should be brought to a level surface, and topped by regular trestle caps 10 to 16 ft. long, to support the stringers. For wide openings, cribs (with one end pointed to facilitate handling in the current) may be towed or floated out to form foundations for crib or frame piers, being sunk by stones onto the natural bottom or onto a pile of stone first dumped. An opening of 15 to 25 ft., with firm sides, such as a washed-out culvert, may be spanned by two 12×12-in. timbers under each rail (6 ins. apart), resting on a sill at each end. These are crossed by about four smaller timbers carrying two 12×12-in. stringers for the rails or ties. Cofferdams are sometimes built for repairs to piers or abutments. The sheet piling for these may be driven by a 700-lb. hammer in 12-ft. leaders suspended from a derrick boom. For work done on dry ground,

after a flood, cribbing may be built to carry the track across the gap. Where an embankment has been narrowed by side wash, cribs may be set or piles driven parallel with it. Caps are then laid with one end resting on the piles (or cribs) and the other resting on the remaining part of the bank.

Roadmasters and bridge foremen should be furnished with lists and condensed descriptions of all steel structures and timber trestles and bridges. They should have blue-prints with bills of material for from 1 to 30 panels of trestle, and for frame and pile bents from 10 ft. to 50 ft. in height, with sway braces and longitudinals or sash girts. These will greatly assist in ordering and preparing material for rapid reconstruction. The foremen in charge of emergency repairs to bridges, etc., should be selected for their judgment and self-reliance, as well as skill, since they may often be thrown upon their own resources. Great care should be taken to insure strong and substantial construction in temporary work. Ample longitudinal bracing should be provided, so as to distribute the pressure and prevent the collapse of a structure by undue pressure upon an unevenly supported bent. At washouts, the liability of a second flood or of heavy floating pieces being carried down by the stream must be borne in mind.

On the Norfolk & Western Ry., the work of repairing washouts is usually carried out by the master carpenter and the division forces, who report directly to the division superintendent. These washouts are usually bridged by frame or pile trestles, depending on the nature of the bottom; and the trestles are put in by carpenter forces with ordinary tools. Occasionally they are assisted by a wrecking car (to clear away debris) and a track pile driver. For example, at Glen Jean, Ohio, 400 ft. of bank, from 16 to 24 ft. high, was washed away by the Scioto River. A frame trestle 400 ft. long was built across this washout by 37 men in 2½ days, all bents being raised by hand; the only tools available were the ordinary carpenters' tools. At Little Otter, Va., 208 ft. of a steel viaduct, 85 ft. high, was wrecked by a derailed train, and 22 cars of coal went down. This opening, 208 ft. long, and 85 ft. high, was bridged by a frame trestle in three days by 75 bridge men. In this case, the wrecking car assisted in removing the debris. On the Boston & Maine Ry. this work is done by the carpenter crews working under the direction of the supervisor of bridges and buildings, who reports to the division superintendent. The washouts are generally not serious enough to require anything but cribbing, and derrick cars are used. However, the road has three pile drivers, capable of driving piles 15 ft. ahead of the front axle. Where a large bridge or a high bank goes out, the carpenter forces from several divisions are sometimes bunched; in this case they work together under the supervisor of the division on which the trouble occurs. More or less timber of all kinds is constantly on hand on the various divisions, and where a large amount is needed it is gathered from the most convenient points where it is stored.

Work-train gangs on the Vandalia Ry. in 1903 ballasted, lined and surfaced track under 12 to 15 ins. of water, in order to reach a washout. This was 45 ft. wide, with 20 to 25 ft. of water, and was bridged while the water was 15 ins. above the track level. The pile driver set a bent of piles, followers being used to put the piles down to 4½ ft. under the water. A cap was then put on, the drift bolts being driven by a follower in a 2-in. pipe. The track was blocked up on the cap; the pile driver moved forward, and another bent was driven and capped. Five bents were thus erected. Although a drop ham-

mer was used, its blows were so well adjusted as to drive all the piles of one bent to the same level. The suspended track was raised by blocks and jacks to permit of putting stringers under the ties; the stringers were then fastened to the cap, and the ties to the stringers, by drift bolts driven as above described. Row boats and timber rafts were used in delivering material to the bridge, and regular shifts were arranged for the men working in the water. The train reached the washout one morning, and the trestle (under water) was completed soon after midnight.

A through-truss double-track 220-ft. swing bridge of the Erie Ry. at Cleveland, Ohio, had one arm wrecked by a derailed train at 5 p.m. on Oct. 21, 1907 The wreckage blocked the channel mainly used for navigation, and had to be cut away and removed before any other work was done. The other arm was left to form a fixed span, and a single-track plate-girder swing span was erected on a foundation of piles and grillage in front of the old abutment. This had a channel arm of 85 ft. (to the old center pier) and a counterweighted shore arm of 48 ft. The bridge was built of a 95-ft. bridge then on the cars for shipment at one point and 37-ft. girders specially built at the bridge shops. The ends were temporarily wedged and locked with regular splice bars bolted to the bridge and approach rails, until more permanent devices could be prepared. Pile driving was started on Oct. 25, falsework erected by Nov. 6, and the bridge put in service at 8 p.m., Nov. 7. (" Engineering News," April 2, 1908.)

CHAPTER 29.—RECORDS, REPORTS AND ACCOUNTS.

Records.

It is of great importance that complete records should be kept of the physical characteristics and equipment of the railway; and of its maintenance, improvements, contracts, purchases, expenditures, etc. It is equally important that these should be kept on a comprehensive system which will enable information to be obtained readily and surely, and which will be coordinated with the railway accounting system. The records will include real-estate and right-of-way properties, rails, ties, fences, bridges, signals, stations and buildings, tunnels, yards and terminals. Also the force and work of the maintenance-of-way department. Some of these have been dealt with under appropriate headings, and others are discussed below. Classified lists of physical equipment are often kept in tabular form on large sheets or in books. These are convenient as office records, but lack flexibility and availability for use or reference. Filing cases are valuable devices in keeping together in some systematic arrangement the correspondence, drawings, accounts, reports, papers, etc., for any one subject or item of work.

The card-index system affords great facilities for simplifying the keeping and filing of records, and it also makes them more available than under any other system. This applies to such permanent records as those of rails, bridges, structures and land; and to the periodical reports of labor, work and material in the construction, maintenance and operation. The system as applied to engineering work was described in "Engineering News" of Aug. 2, 1906. It is used by several railways for keeping ledger accounts with individual con-

tracts or pieces of work. In this way a full record or statement for each account is shown on the card, without confusion with other accounts. Records of rails, ties, fences, track work, requisitions, purchases, material, etc., can be conveniently kept on cards. Records of bridges and bridge inspection are also kept in the same way, as noted elsewhere. The system has been introduced also in the right-of-way, accounting, purchasing, operating and motive-power departments, and can be applied to various classes of records for the engineering and maintenance-of-way work. The two sizes of cards most generally used are 3×5 ins. and 5×8 ins. A record of improvement work may be kept by cards of different colors for different classes of work. These are arranged between guide cards having raised tabs for the names of stations. Thus if ballasting is being done between Greytown and Brownville, the information may be entered on a buff card (for ballasting) filed behind the index card lettered Greytown. Particulars of double tracking and installation of signals between Brownville and Greenboro may be entered on blue (relaying rails) and pink (signaling) cards behind the card lettered Brownville. Each card would show the location of the work, a brief description, the index number of correspondence file, the number of order authorizing the work, and the dates of ordering, commencing and completing work. If it is desired to know what amount of signal work, for instance, is in hand, all the pink cards can be taken out and a summary prepared. The amount of clerical work required for keeping up the records and keeping the files in order is small when compared with the many advantages of the systematic records.

Track Charts.—Most railways keep some form of map or chart record which shows the alinement and profile, track plan, and the important physical features (including those relative to operation). The charts may be arranged in book form or as large plans for office use; they may also be in long slips that can be folded for the pocket. Whenever changes are made, the charts should be corrected and revised copies then sent to the general office. Corrected copies of the entire chart should be issued at least once a year. The chart should include both plan and profile, and would usually show the following features: all main and side tracks, and their spacing c. to c.; lengths of sidetracks (with car capacity); industrial spurs; junctions; all stations and other buildings on the right-of-way (or closely adjacent), with their character and dimensions; turntables and roundhouses (with diameter and capacity respectively); water and coaling stations; shop buildings; telegraph lines (with number of wires); water mains, sewers and electric wires or conduits; fences; street, road and farm crossings; track crossings of street, electric and steam railways (with their angles); tunnels; bridges, trestles and culverts (with particulars as to spans); signals and interlocking; weight and age of rails, character of ballast and other track features; section limits; county and other boundaries; property monuments, and survey stations. The limits of right-of-way should be marked, but all information as to ownership, etc., is shown on the right-of-way map. The rated loading for freight engines, the ruling grades, and the weight of engine which may safely be run (as limited by roadway or bridges), may be indicated. The American Railway Engineering Association in 1907 adopted a series of conventional signs for track charts. The scale may be from 300 ft. to 5,280 ft. to the inch, but for station or terminal plans it may be about 100 ft. to the inch, or even 50 ft. where extensive industrial developments have to be shown.

In Fig. 232 is shown a portion of a division chart used by the Chicago & Northwestern Ry. The sheets are 34×52 ins. inside the border lines; the horizontal scale is 1 mile to the inch, and the vertical scale 100 ft. to the inch. In one corner is a small map of the division. The charts are corrected annually. Blue prints are framed for office use, and are cut into strips and folded for pocket use. At the top are shown the track sections and mile posts, and a line is ruled across the chart at each mile. Then comes the alinement, showing the degree of each curve. Below this is a general plan, the railway being indicated by a straight line. Bridges, road crossings, sidings, spur tracks, buildings, etc., are shown, and notes are given as to spans of bridges, grades

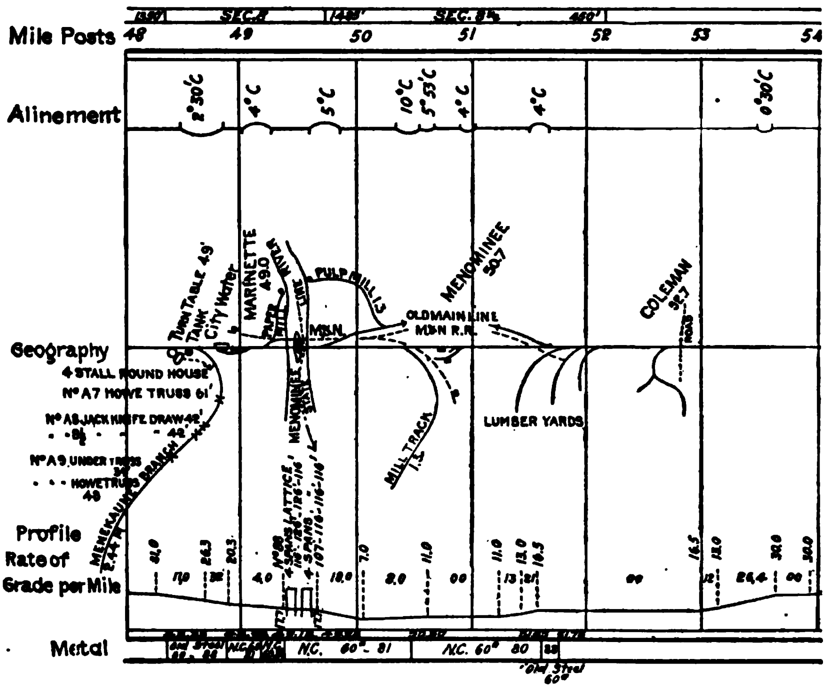


Fig. 232.—Track Chart; Chicago & Northwestern Ry.

of spurs, and capacity of roundhouses. The township and other boundaries are marked. Under this is a profile, on which bridges are described, and elevations and grades also noted. The profile is broken, if required, to keep it below the plan. At the bottom of the chart are shown the make, weight and date of rails. Station and yard tracks are indicated merely, reference being made to yard plans. Sidings and spurs are not plotted to scale. With each sheet is a table showing the dates of construction, and another table giving the location of each bridge, its record number, and its clearance in width and height.

A chart used by the Pennsylvania Ry. is 6 ins. high, folding up to 4×6 ins. It is divided vertically by sections instead of miles, with the names and addresses of the supervisors and foremen along the top of the chart. The plan

shows the state and county lines, mile posts, number of tracks (and, by symbols, the weight of rail), sidings, road crossings, bridges (with their numbers), stations, signal towers (with their telegraph calls and the number of the block), etc. Below this is the alinement plan, showing the direction and degree of curves. Symbols on this line indicate the character of the ballast. Below this again is the profile. The Atchison, Topeka & Santa Fé Ry. has a rail, ballast and fence record consisting of process sheets (blue lines on white ground) 13×8 ins., divided vertically by lines forming a scale of 1 in. to the mile, with five strips of track on each page. Each strip of track has three lines, the center line indicating the rail and ballast, and the two side lines the fences. Numbers and symbols indicate the kind of ballast, weight of rail, kind of fence, etc.

Rail Records.—The set of rail-record blanks as used on the Pennsylvania Ry. and the Pennsylvania Lines comprises the following: (A) Manufacture: 1, Report of chemical and physical examination; 2, Certificate of inspection. This gives a statement of rails accepted and rejected, with the reasons for rejection; 3, Report of shipment from mill. All these are signed by the inspector and the engineer of tests. (B) Failures: 4, Report of section foreman on broken, damaged and defective rails removed from main track. This is similar to the report noted later; 5, Report of superintendent on rails which have failed. This is made monthly, being compiled from the foremen's reports; 6, A summary of rail failures for a number of years, the rails being grouped as to weight and make; 7, A comparison of failures of rails of different weights, sections or makes. (C) Statistics: 8, Division engineer's annual report of the different kinds of rail in main track; 9, Diagram (1-in. per mile) showing the location of all rails of a certain kind that have been sent out for trial; 10, Diagram (2 ins. per mile) for reporting a single group of a special kind of rail under trial; 11, Diagram of wear. Rail sections drawn or printed on this sheet have the worn contours plotted from actual measurements.

Bridge Records.—Records of the bridge department have been dealt with in the Proceedings of the American Railway Engineering Association, 1904–06–07. The records of the character and design of bridges and culverts may be kept in accordance with the following system, as recommended by the above Association: 1, The chief engineer or other officer having charge of the design and maintenance of these structures should have on file complete plans of each structure. showing its details, its location, and the physical characteristics of the ground within a reasonable distance. 2, Changes in any structure should be reported to the head office, and noted at once on the record plans. 3, Blue prints of the general and detail plans should be furnished to division officers having charge of the maintenance of structures. 4, Photographs of the record tracings may be furnished to the division or other officers fo. use in the field; these would be of a size convenient for the pocket and bound in book form. A condensed record of all structures is almost indispensable for office use and reference. The bridge record is sometimes a blue-print list, corrected from time to time. This shows the bridge number, the position (by miles), number and length of spans, center height, general description, and year of construction. Many roads have a tabular record of structures. One form is a sheet 16×21 ins., with main headings as follows: Steel bridges, trestles, culverts, viaducts, tunnels. These are subdivided to show style of piers, trestles with bents of treated or untreated timber, style of culvert, tunnel dimensions, length of structure, etc.

For bridge records and bridge-inspection records the card-index system of filing is specially adaptable. In Fig. 233 is shown the face of an index guide card (8×5 ins.). There is a card to each bridge, and upon it is given full information as to the structure; its location, type, dimensions, age, loading, foundations, repairs, etc. The back of the card may be used for additional information or for a sketch of the structure. The cards give also the file numbers of the drawings, correspondence, etc., relating to each structure. Reports of inspections are entered on cards of the same size (but sometimes of a distinctive color). These are filed behind the index cards of the structures. In this way full particulars of the condition, repairs and maintenance expenses of each bridge, and the location of drawings and correspondence relating to it, can be ascertained very quickly. The inspection card used in connection with the index card shown in Fig. 233 has the same heading as the latter,

No. Spans	Extr. Length	Design		BRIDGE No.	5860 13
Over	on		DISTRICT		DIVISION
Width	c. to c. Depth	No. Panels	Length	c. to c. =	
Built by	in	Chords = E	Beams = E	Stringers = E'	

Weight of One Span	Sub-foundation
Cost per lb. cts.	Abutments of amt. cu. yds.
B. of R. to Top of Masonry	Piers of amt. cu. yds.
B. of R. to Underclearance	Ties , x x ft. lg. spaced c. to c.
Clearance, height, width	Alignment Super-elev. in.
Underclearance to High-water	Grade %. No. of Tracks
Drainage Area sq. ft.	Notes:--
Required Waterway sq. ft.	
Actual Waterway sq. ft.	
Correspondence file	
Profile Drawings	
Masonry Plans	
Sho[illegible]ils	Should be inspected times per year
Erection Plan	Span replaced 19

Fig. 233.—Bridge Record Card.

with a note "Should be inspected —— times per year." Below this the card is divided into nine columns for the following information, with 12 horizontal lines for as many inspection records: Name of inspector; month, day and year; condition of superstructure, foundations, deck and paint; date of last painting. In some cases a card is used for each inspection, giving details of the condition of the several parts. (See also "Bridge Work.") The indexing of the cards is by the bridge numbers or by mileage. To facilitate reference, the location of each station may be indicated by a card of distinctive color or with a raised tag for the name. On large railways, separate files would be kept for the different divisions. This system of bridge records is used by the Atchison, Topeka & Santa Fé Ry. and the Michigan Central Ry. On the latter, colors are used to indicate the different classes of structures; buff cards are for steel bridges, yellow for wood, pink for arches, green for culverts, etc. These are all numbered and arranged consecutively, regardless of color or class.

The right-of-way and real-estate records are incidentally related to the engineering and maintenance-of-way departments. They are dealt with in the Proceedings of the American Railway Engineering Association for 1905 and 1908. On the Chicago & Northwestern Ry. all such matters are in charge of a land department, and the system of records employed (including maps, leases, deeds, etc.) is described in the Proceedings of the Illinois Society of Engineers, 1903 ("Engineering News," Jan. 29, 1903).

Reports.

Numerous periodical reports from subordinate officers to their superiors are necessary to show the work of the maintenance-of-way department and to enable its progress and cost to be determined. These reports relate mainly to labor, work and material, and from them the cost is distributed in the accounting system. They are usually made in books or on ruled sheets or forms. The sizes and styles vary widely on different railways, but it is advisable to have as few sizes as possible, for the sake of uniformity and for convenience in filing. In many cases the reports received by one officer are compiled or summarized in his own report to the next superior officer. Thus the foremen's reports for the several sections may be condensed into the roadmaster's report for the division, and the roadmasters' reports for the several divisions may be condensed into the engineer's report for the entire line. The reports for the use of section foremen, bridge and building foremen, work-train conductors, etc., should be as simple and clear as possible. These men are usually of limited education, and have little understanding of the details of a system of accounting. But upon their reports this system is largely based. Complicated analysis or distribution of work should not be required of these men, and would be accomplished very unsatisfactorily (and incorrectly) by them as a rule. The aim should be to have simple, accurate and definite statements or reports from the men. The analysis and distribution for statistical or accounting purposes would then be done more accurately and economically in the office of the roadmaster or engineer. The office should have, of course, a sufficient force for the purpose. This system is employed by the Pennsylvania Lines. The roadmaster receives the monthly time books (which are practically labor reports) from the various foremen. He examines, checks and approves these, and then forwards the original reports to the engineer. In the engineer's office the pay rolls, reports and compilations are made.

The reports used vary widely on different railways, but the list in Table No. 41 summarizes the reports most generally used.

Reports of the material and tools on each section and division are very important. A daily record of material is usually kept by the section foreman in a small blank book, and from this he prepares a monthly inventory or report. The reports are sent to the roadmaster or supervisor, who either compiles his report from them or sends them (when examined and checked) to the engineer. The several reports are then combined and summarized, and a classification prepared of expenses for material. The form of monthly report as recommended by the American Railway Engineering Association (1905) is shown in Fig. 234. This is on a sheet 17×14 ins., and is designed to give a complete check upon all material received and used. Column No. 4 includes material received through purchases; No. 5, that removed from track during repairs; No. 6, that removed from abandoned tracks. These last two

are often combined. The description covers the various kinds of material and their various classes as to weight, size, etc.; for instance, rails of different weights, frogs of different numbers, long and short splice bars. For track scrap, only four classifications are given: 1, Rail 6 ft. and over; 2, Rail under 6 ft.; 3, Frog, switch and guard rail; 4, Miscellaneous. It has been suggested that a more detailed description should be given, as by subdividing all the vertical columns to separate "usable" and "scrap" material of each class in the list. On the other hand, an individual or ledger account is rarely kept with each track section, and it is difficult to get detailed reports made out completely and accurately. It is considered doubtful, therefore, if the railway company would benefit appreciably by the more extended classification. The Pittsburg & Lake Erie Ry. has a form of report of scrap on hand available for sale. This is made out monthly by the assistant engineer, and is sent by the chief engineer to the purchasing agent. It gives the first three classifications noted above, and the following: 4, Track scrap (A, Bars, bolts, spikes, etc.; B, Miscellaneous wrought scrap; C, Miscellaneous cast scrap); 5, Bridge scrap; 6, Miscellaneous scrap (wrought, cast and malleable).

TABLE NO. 41.—LIST OF REPORTS.

Section Foreman to Roadmaster.

Time book (Monthly).	Tools and equipment (Monthly).	
Work performed (Weekly or Monthly).	Material and scrap (Monthly).	
Fencing (Weekly, during renewals only).	Fires, Stock killed,	Occasional.
Rails removed (Monthly).	Accidents to trains,	
Ties laid and removed (Weekly).	Broken or defective rails, etc.	

Roadmaster to Engineer.

Distribution of pay roll.	Broken rails.
Work performed.	Broken joints.
Rails laid and removed.	Switches and frogs removed.
Ties laid and removed.	Work-train work.
Track ballasted.	Extra-gang work.
Sidetracks laid and removed.	Gravel and earth handled.
Materials and scrap.	Bridge inspection.
Tools.	Train and other accidents.
Fencing.	

Miscellaneous.

Work-train foreman	to	Roadmaster	Daily
Extra-gang foreman	to	"	"
Bridge foreman	to	Sup. Bges. & Bldgs	Daily
Do., materials	to	" " "	Monthly
Carpenter foreman	to	" " "	Daily
Do., materials	to	" " "	Monthly
Steam-shovel engineman	to	Roadmaster	"
Pump-station engineman	to	Sup. Bges. & Bldgs	Weekly
Tie inspector	to	Engineer	Daily
Signalman, condition of sig. or int. plants	to	"	Weekly
Do., tools and material	to	"	Monthly
Inspector on contract work	to	"	Daily

Remarks and explanations may be made on the back of the material report, and the foremen should be trained to use the report properly and to make all necessary explanations. The back may also have a tabular form for daily report of material received by shipment and shipped away. This serves as a check upon columns Nos. 4 and 12. It shows the date, quantity and description, from whom received or to whom shipped. In some cases the foremen simply make daily reports of material used and for what purpose. The office force combines these into a monthly statement. This provides for separating the material (and cost) for maintenance work from that of new work, such as new sidings and extension of sidings. This is sometimes provided for, however, by a separate report of sidetrack work, or by entering in columns Nos. 10 and 11 of Fig. 234 the name of new track and the number of order authorizing the

Sub-Division .... Section No. .... For Month Ending ....

1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Unit	On Hand at Date of Last Rep't	Rec'd. during the Month			Total to Account for	Used and Shipped during the Month					Total Disposed of	On Hand at date of this Report
			By Shipm't.	Taken out of Track	From Track Taken up		Repairs		New Tracks		Shipped away		
							Main Track	Sidings					
Rail....new....1st Class........ lbs. per yd.													
" .... " .... " .... "													
" .... " ...... 2nd Class .... "													
Rail relaying .... "													

Fig. 234.—Monthly Report of Material (American Railway Engineering and Maintenance-of-Way Association).

Monthly Inventory of Tools and Equipment on ....{Branch or Division} for ....189__

Road Masters will show only new tools in stock, the equipment (or Engineers Dep't tools on wheels) on his Division, and the total number on his territory, of the large tools marked "new and 2d hand." Second hand tools in stock or in the hands of his men are not to be included.

KIND OF TOOL		On Hand ....1st.	Received	Shipped	Used	On Hand ....1st.	KIND OF TOOL		On Hand ....1st.	Received	Shipped	Used	On Hand ....1st.
Axes, Chopping,	New, No. of						Dippers, Drinking	New, No. of					
" Hand,	" "						Drills, Ratchet	" "					

Fig. 235.—Roadmaster's Inventory of Tools.

work. Reports of tools and equipment are made by the foremen. These are similar to the material reports, and are handled in the same way. Fig. 235 shows one form of roadmaster's inventory, consisting of two sheets $8\frac{1}{2}\times14$ ins. This is sent to the engineer or the auditor.

Reports of work done on the sections are made weekly by the section foremen. The report used by the Pittsburg & Lake Erie Ry. is a sheet $8\frac{1}{2}\times11$

SECTION No. .... SUB-DIV. No. .... DIVISION.

WEEK ENDING ....

RENEWING AND SPACING CROSS TIES.

	Renewals			Spacing Ties		
	No. Cross Ties	No. Hours Work	Kind of Ballast	No. Ties Moved	No. Hours Work	Kind of Ballast
Number Cross Ties—Main Tracks.						
" " " —Sidings.						
Total.						
Average Number Cross Ties Per Hour.						

REPORT OF MARKED TIES REMOVED FROM TRACK.

Removed from Main Tracks				Removed from Sidings			
Number Removed	Year Put in as Marked on Tie	Kind of Timber	Cause of Removal	Number Removed	Year Put in as Marked on Tie	Kind of Timber	Cause of Removal

NEW RAILS LAID IN RENEWALS.

	New Rails Laid			Kind of Angle Bars	Cross Ties Moved	
	Ft. 90 lb.	Ft. 80 lb.	Number Hours Work		Number Ties Moved	Number Hours Work
Number Feet New Rails in Main Tracks.						
Number Feet New Rails Laid in Sidings.						
Total.						
Average Number Per Hour.						

Unusual Work Done:

Business Sidings Built:

Progress of Work:

....
Foreman.

INSTRUCTIONS:—Report to be sent to Supervisor on 7th, 14th, 21st and last day of month.
Foreman's time to be included in distribution.

Fig. 236.—Section Foreman's Weekly Report; Pittsburg & Lake Erie Ry.

ins., of the form shown in Fig. 236. The foreman includes his own time in the report, and after signing it he sends it to the roadmaster on the 7th, 14th, 21st and last day of each month. It may be stated that the season's work is carried on in accordance with a well-defined schedule. In another form of work report, the sheet is $5\frac{3}{4}\times9\frac{1}{4}$ ins., and is not ruled in columns. At the left is a list of work, including the following: Number of men, total days of work (as per time book), frogs and switches examined, rails laid, ties laid, track

surfaced (with its location), track ballasted, ditch made or cleaned, condition of hand cars, etc.

Reports of main track ballasted, made monthly by the roadmasters, may have vertical columns headed as follows: Between what station stakes, which track, feet of track ballasted, kind of ballast, cubic yards deposited.

Reports of ties received, laid, removed, shipped, burned, etc., are made by the foremen. They should show the kind of wood, and should separate main track and sidetrack work. It is important to record the date of laying and removing ties, but this is rarely done except in the case of treated ties which are marked with the year of treatment. For such ties, the foreman should report (daily or weekly) the number laid, location, date mark on tie,

CHIEF ENGINEER'S DEPARTMENT.

REPORT OF RAIL LAID IN MAIN TRACK.

On the____________________Division. Month of____________________190_

	RAIL LAID.							RAIL REMOVED.		
	Survey Station. From.	Survey Station. To.	Northbound or Southbound	Feet of Track.	Brand and Date of Rail	Weight per Yard.	New or Old.	Brand and Date of Rail.	Weight per Yard.	
1										1
2										2
3										2

Fig. 237.—Report of Rails Laid and Removed; Pittsburg & Lake Erie Ry.

kind of wood, treatment. These reports will be used in the office in preparing statistics of ties. For treated ties removed, the American Railway Engineering Association recommends a monthly report ruled in 10 columns to show (for main track and sidetrack separately) the number of removals, year marked on ties, kind of wood, kind of treatment, and cause of removal. The first column gives the number of ties removed bearing the date given in the second column. Reports of ties inspected are made by inspectors, and of ties treated

Division__________ Sub-Division________ Date__________19

Location	Track No.	Facing or Trailing	Stand Kind	Stand Throw	Points Cond'n.	Frog Kind	Frog Cond'n.	Guard Rail Throat	Gage at Frog	Remarks.

Fig. 239.—Report of Main-Track Turnouts; Pittsburg & Lake Erie Ry.

by the superintendents of preservative plants (or by inspectors). Notices of ties shipped for distribution are sent by the engineer to the roadmasters.

Reports of stretches of rails laid on main track are made monthly (during the time of rail renewals) by roadmasters on the Pittsburg & Lake Erie Ry. The sheet is $8\frac{1}{2} \times 11$ ins., with headings as in Fig. 237. These columns cover half the sheet and have 15 horizontal lines. Below them are 15 lines (numbered) for remarks referring to the lines on the tabular part of the report.

Reports of frogs and switches removed from the track are made in considerable detail by roadmasters on the Pittsburg & Lake Erie Ry. The form is

shown in Fig. 238, and is on a sheet $8\frac{1}{2}\times 11$ ins. The report must be made after personal inspection, and must show the day of removal. This report is used as the basis of an annual summary showing the life of frogs and switches.

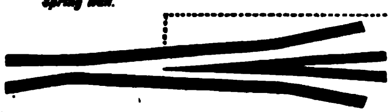
.... DIVISION.

REPORT OF FROGS AND SWITCHES REMOVED FROM TRACK.

Date, ... 19....

Section No. .... Station .... Survey Station .... + ...

Name of Track .... Main or Side Track ....

FROGS	SWITCHES
No. .... Length .... Weight of Rail	Length .... Weight of Rail ....
Spring or Rigid .... Right or Left Hand	Split or Special ....
Bolted or Keyed .... New or Old When Laid	Main or Side Track Point .... Right or Left Hand ....
If Special Make, give name	Part Damaged, Broken or Worn Out ....
Name of Manufacturer	New or Old When Laid ....
Show Location of Break on Sketch. If Spring Frog, mark Spring Rail.	Distance of Break from Point ....
	Condition of Stock Rail ....
	Name of Manufacturer ....

CAUSE OF REMOVAL—BROKEN.—State Cause and Condition of Point Broken ....

....

DAMAGED OR WORN OUT.—State Exactly in What Way ....

....

DEFECTIVE.—Locate any Flaws and State Cause ....

....

CONDITION.—Fit for Use, Scrapped or can Repairs be Made? ....

By Whom can Repairs be Made? ....

State if any Accident or Delay was Caused ....

....

Kind of Ballast .... Condition of Ballast ....

Condition of Ties .... Line .... Surface ....

Date Laid—Year .... Month .... Date Taken Up—Year .... Month .... Life in Track—Years .... Months ....

INSTRUCTIONS.
Supervisors will make this report from personal inspection for every Frog and Switch of over 71-lb. rail removed from track. Date report day Frog or Switch is removed from Track.

Correct.

....
Supervisor.

Fig. 238.—Report of Frogs and Switches Removed; Pittsburg & Lake Erie Ry.

Monthly reports of main-line turnouts and their condition are also made by the roadmasters. The sheet is $8\times 10\frac{1}{2}$ ins., with headings as shown in Fig. 239.

Reports of sidetrack work are made on a number of railways, and Fig. 240 shows the form used for the monthly reports made by roadmasters on the Grand Rapids & Indiana Ry. The sheet is $8\frac{1}{2}\times 14$ ins. The list of material

includes the following: Rails, joints, track bolts, spikes, rail braces, ties, switch ties, frogs, switches, switchstands, switch locks, and switch lamps. Instruc-

_______________ DIVISION.

MONTHLY SIDE TRACK REPORT FOR _______________ 190__

Name of Siding _______________ *connecting with* _______________

Located at mile-post ________ *plus* ________ *feet north, running in* _______________ *direction*

_______________ *side of main track.*

DATE			LENGTH IN FEET					
AUTHORIZED	BEGUN	COMPLETED	NEW	ORIGINAL	EXTENDED	TAKEN UP	PRESENT	CLEAR

KIND OF MATERIAL		NEW	OLD		PRICE	AMOUNT
Steel rails ______ pounds per yard	Feet					
Joints	No.					
Track Bolts	Pounds					
Spikes	"					
Rail Braces	No.					
Cross Ties, kind	No.					
Switch Ties	Feet					
Frogs, kind ______ No.	No.					
Switches, kind	No.					
Switch Stands, kind	No.					
Switch Locks	No.					
Switch Lamps	No.					
TOTAL						

KIND OF LABOR	HOURS						
	Section Men	Extra Gang	Work Train				
Grading							
Putting in switch							
Laying rails and ties							
Hauling ballast							
Putting in ballast							
TOTAL							
GRAND TOTAL							

INSTRUCTIONS.

A sketch of the track, showing connections, must accompany this report

The columns "Price" and "Amount" are for use in M. of W. office only.

All lengths except "Clear" to be figured from point of switch.

The above statement is correct.

____
ROADMASTER.

Fig. 240.—Report of Sidetrack Work; Grand Rapids & Indiana Ry.

tions on the report state that a sketch of the track, showing connections, must accompany the report. The columns of price and amount are for use in the

maintenance-of-way office only. All lengths (except "clear") must be figured from the point of switch. This report is for one piece of work. Forms of monthly reports covering all the sidetracks built and removed during the month are shown in Fig. 241. These are sheets 10×8 ins.

NEW SIDETRACKS CONSTRUCTED,.............Division..........,190..........

AT WHAT STATION.	NAME OF TRACK.	LOCATION BY STATION STAKES.		FEET OF TRACK CONSTRUCTED.	REMARKS.
		FROM	TO		

SIDETRACKS TAKEN UP,.................Division... ...., 190.............

AT WHAT STATION.	NAME OF TRACK.	FEET OF TRACK TAKEN UP.	KIND OF RAIL.	KIND OF SWITCH REMOVED, IF ANY.	REMARKS.

Fig. 241.—Reports of Sidetrack Work.

Reports of fence and ditch work are made weekly by section foremen on the Grand Rapids & Indiana Ry. They are sheets 8½×5½ ins., with a line for each day and the total. Each has columns for date, location by station stakes, which side of track, total hours of work, and remarks. The fence report has columns for length of fence built (rods), number of posts set, and rods of wire used. The ditch report shows length of ditch built, length of tile laid (feet), and number of tile laid. A form of daily report for a fence gang is a sheet 8½×10¾ ins. It shows the number of men, length and kind of fence built and repaired, cattleguards built and repaired, number of post holes dug and posts set, kind of soil, etc. A form for a roadmaster's monthly report of fence work is shown in Fig. 242, and is on a sheet 8½×14 ins.

FENCE CONSTRUCTION ON.................Division, during.........., 190 ......

Locations by sta. stakes.		Which side of track.	Feet.	Kind of fence.	Cost.			New or old material.	Remarks.
From	To				Labor.	Material.	Total.		
....	....	....	....	....	......	....	....	......	....
....	....	....	....	....	......	....	....	......	....

Fig. 242.—Roadmaster's Report of Fence Work.

Reports of the gates at highway crossings are made monthly on the Grand Rapids & Indiana Ry. The sheet is 8 ins. wide, ruled in vertical columns for the following information: Name of crossing, location, pattern of gate, date of inspection, condition, date of repairs, and remarks. Reports made weekly by pumping-station men may show the size and style of engine, pump, boiler and tank; hours pumped, fuel consumption, supplies received and used, and condition of plant. If a water-softening plant is used, special additional information will be required. Reports of inspections at stations are sometimes made

daily to the master carpenter or foreman of buildings. These may be sheets $8\frac{1}{2}\times 14$ ins., one for each station. At the left is a list of parts and a column for noting the condition when inspected; more than half the page is left blank for remarks. The list may include: passenger station, freight station, other

.... Division Engineer. .... 190....

Dear Sir:

Work train was called for..................*M. at*..................

was ordered to report at..................*at*..................*M. to-day: arrived at*..................*M*

and left at..................*M. Was delayed*..................*hours in starting and going to work, as follows:*

COMMENCED WORK at..................*at*..................*M. with*..................*Men and did the following:*

KIND OF WORK. Separate different Jobs. Describe each fully. Show kind and quantity of material and number of Cars of each loaded; also kind of cars.	Time Charged to Each Job. Train.	A M. W. Men including Foremen.
Total Time, (of Train from commencement of work to close.)		
Total Time, (of M. W. Men to agree with total time allowed.)		

While working was delayed..................*hours, as follows:*..................

..................*FINISHED at*..................*M.*

Used Engine No................... *Engineer*..................

Conductor,..................*Number of Brakeman*..................

State of Weather..................

Approved:..................

Foreman.

NOTE—Give each delay and time lost thereby separately, Forward to Division Engineer on same day train was used.

(LEAVE THIS TABLE BLANK.)

HOURS.	CHARGED TO	WAGES Conductor	Brakeman	Engineer	Fireman	Fuel.	Stores.	Repairs.	Total.

Wages of M. of W. Men, ... $..................

Total cost of work Train, ... $..................

Fig. 243.—Work-Train Report; Baltimore & Ohio Ry.

buildings, water tank and tower, water columns, pump house, coaling station, stock chutes, mail cranes, freight derricks, track or wagon scales, crossing gates, etc. The foremen of buildings may make weekly reports of work done, number of men, the time for each day and for the week, the wages, and amount.

Reports of work trains and extra gangs are made daily by the foremen,

being sent to the roadmaster or engineer. On the Grand Rapids & Indiana Ry. the report is a sheet $8\frac{1}{2}\times10\frac{3}{4}$ ins., having a wide column for description of work and a narrow column for the hours chargeable to each kind of work. The instructions require the foreman to make a complete diary of the work done, describing each job; new sidings and extensions must be separated from other work. On the Pittsburg & Lake Erie Ry., work-train conductors send reports to the assistant engineer each night. The report is a sheet

CHIEF ENGINEER'S DEPARTMENT.

DAILY REPORT OF EXTRA FOREMAN.

On what piece of work engaged...190

Work Train Engine No.................. Reported for duty at..................M. Went off duty at..................M.

CARS LOADED.					CARS UNLOADED.				
Initials.	Numbers.	Sec. No.	Contents.	At What Point.	Initials.	Numbers.	Sec. No.	Contents.	For What Purpose.

HANDLED FROM STEAM SHOVEL.

No. of Flat Cars Loaded.................., Unloaded.................. Kind of Material..................
" Gondolas " .... " .... " ....
" " .... " .... " ....
" " .... " .... " ....

DAILY DISTRIBUTION OF LABOR.

Extra Foremen should fill out this blank each night and forward to their superior.
The Distribution of Time should be taken from the book in which it is kept, the object being to obtain, daily, a record of how much time is being expended on each piece of work, or portion of it.

DISTRIBUTION OF LABOR. (EXCLUSIVE OF TEAMS AND DRIVERS.)	Section Number.	Number of Men Working.	Total Hours Worked.	AMOUNT.	
				$	Cts.
Teams and Drivers—Give Number..................					
Total					

....Extra Foreman.

NOTE.—Time of Foreman should always be included.

Fig. 244.—Extra-Gang Report; Pittsburg & Lake Erie Ry.

$5\frac{1}{2}\times8\frac{1}{2}$ ins., with headings to indicate the work, the time of going on and off duty, the number of locomotive, etc. The greater part of the sheet is blank, for a summary of work done and particulars as to the cause and length of any delays. The form of work-train report of the Baltimore & Ohio Ry. is shown in Fig. 243.

On some roads, however, the daily work-train report shows the number (and kind) of cars of gravel and of earth unloaded, and at what points; also the number (and kind) of cars held in service for the next day. The extra-gang's report may show the number of cars loaded and unloaded, and points where unloaded. Foremen of extra or floating gangs on the Pittsburg & Lake Erie Ry. make daily reports on forms $8\frac{1}{2}\times10\frac{3}{4}$ ins., shown in Fig. 244. Two reports of similar work, made daily by the roadmasters of another railway,

DAILY REPORT OF EXTRA FORCE,..................................DIVISION.

....189......

This report should be forwarded to Division Engineer daily. "Extra Men" includes all men paid on Road Master's rolls outside of those on Section and Fence Gang rolls. Each gravel pit and such piece of important work, such as a section of second track construction, change of grade, a new yard, or extensive ballasting of old main track, should be kept separate. Gangs or work trains engaged in ordinary miscellaneous work should be shown as doing such.

At What Point, or On What Piece of Work.	Days' Work Performed by Extra Men.					Excavators at Work Numbers of	Number of Work Trains.	Locomotives, Numbers of	Cars in Service of Work Trains at End of Day.			Remarks.
	Conductors and Brakemen.	Men on Excavator Rolls.	Teamsters with Teams.	All Other Extra Men.	Total.				Flats.	Gondolas.	Dumps.	

DAILY REPORT OF GRAVEL AND EARTH HANDLED,..................................DIVISION,.......... ....189...

This Report should be Forwarded to Division Engineer Daily. The material handled on each piece of Second Track, Change of Grade, or other important work, as well as in each Gravel Pit, should be Shown Separately. Gravel unloaded for ordinary main line ballasting on divisions where such ballast has been received from elsewhere, must be likewise treated.

Loaded								Unloaded or Shipped.							Remarks.
At What Point, or On What Piece of Work	By What Means, Excavator or Hand	Gravel			Earth.			On What Piece of Work, or To What Point	Gravel			Earth.			
		Flats.	Gondolas.	Dumps.	Flats.	Gondolas.	Dumps.		Flats.	Gondolas.	Dumps.	Flats.	Gondolas.	Dumps.	

Fig. 245.—Reports of Extra Gangs.

are shown in Fig. 245. They are on sheets 14×8½ ins. The same form of report is used by the work-train foremen in charge of the laborers.

Reports of steam-shovel work are important in enabling the cost of ballasting and filling to be determined. Forms for such reports and for records of the work have been adopted by the American Railway Engineering Association. The daily report should show the style and capacity of the machine, the character and location of the work, and also give the following information:

Information for Report of Steam-Shovel Work.

Time of starting.	No. of cars loaded.
Time of stopping.	Kind of material.
Time for spotting.	Material loaded (cu. yds.).
Actual time worked.	Material per car (cu. yds.).
No. of men at pit.	Condition of track.
No. of men with train.	Weather.
No. of locomotives.	Supplies consumed.
No. of cars.	Haul, average.
Style and capacity of cars.	Delays (time and cause).

Reports of train accidents are required from roadmasters. These specify the train, time, location, and character of accident, together with information as to the points noted below. In some cases the information required is noted on a printed form 8½×14 ins. In case of a serious accident, special investigations and reports are made.

Information for Report of Train Accidents.

Main, side or private track.	Condition of track.
At switch or frog.	Gage of track.
Trailing or facing switch.	Damage to train.
Curve or tangent.	Damage to track.
Curve: degree, superelevation and gage.	Damage to structures.
Track construction (in full).	Cause of accident.

Reports of broken and damaged rails found in the track are of great importance. These do not include rails worn out in service or those broken in train accidents. The report is usually required to be made out by the section foreman. It is checked by the roadmaster, after personal observation, and is forwarded to the engineer. The latter will send copies to designated officers. The report is made on a printed form. This should have a diagram of plan, section and elevation of a rail (showing ties also), upon which the position and character of fracture or defect may be marked. Some roads require the roadmaster to have about a foot of the rail on each side of the fracture cut off, and properly labeled and numbered, for future reference. In describing failures, the following terms may be used: 1, "Broken" indicates a rail broken completely through (and separated into two or more parts), or having a crack which may result in a complete break; 2, "Damaged" includes rails damaged or broken by broken wheels, train wrecks, etc.; 3, "Flow of metal" means a rolling out of the metal to form a lip or fin on the edge of the head, but without indications of a breaking down of the metal in the head (that is, the bottom of the rail head is not distorted); 4, "Crushed head" means a flattening of the head, with the sides crushed down below the original level of the bottom of the head; 5, "Split head" means a rail showing a longitudinal split near the middle of the head, or having pieces split from the side of the head. It should be stated whether this is accompanied by a seam or hollow head. 6, "Split web" means a longitudinal split in the web, usually starting at the end of the rail and running through the bolt holes. 7, "Broken base" includes splits in the base and pieces (usually of segmental shape) broken from the edge of the base. The information required by the report usually covers the points

noted below; the "rail number" means the letter or number indicating the part of the ingot from which the rail was rolled.

Information for Report on Broken Rails.

Weight per yard (original).
" " " (present).
Rail section.
Brand on rail.
Heat number.
Rail number or letter.
Original length of rail.
Date when laid.
Location (mile post and feet).
Which track and rail.
Bank or cut.
Curve or tangent.
Curve, No. and degree.
Curve, superelevation.
Gage of track.
Rail broken, defective or damaged.
Character of failure.
Cause of failure.
Did rail break under train.
Last train (and engine No.) before break.
Amount of traffic and heaviest engine.
Was automatic signal operated by breaking of rail.
Rail badly worn.
By whom discovered.
Date and time.
Was rail removed (date).
Was rail spliced.
Break over or between ties.
Break square or angular.
Distances between ties at break.
Condition of ties at break.
Kind of ties, and age.
Tie-plates used.
Condition of line and surface.
Ballast, material and depth.
Was track properly ballasted.
Material of roadbed (subgrade).
Track well drained.
Roadbed frozen.
Joint, description.
Joint bolts loose.
Spikes loose.
Weather and temperature.
Accident or detention to train.

For reporting progress on track elevation work, the engineering department of the Chicago & Northwestern Ry. uses white prints (blue lines on a white ground) showing a diagrammatic plan and profiles. The plan shows the number of tracks, and the arrangement of the streets. Two profiles show the retaining walls, abutments and bridge superstructures for the north and south sides of the work (the south portion of the piece of work in question being completed before the north portion was started). Six profiles show the sand filling on the several tracks. A distinctive color is used for each month's work, and a colored chart for each week is the only record required of the engineer in charge of the work. A system of reports of tracklaying, used on the Oregon Short Line, has been given in the chapter on "Tracklaying."

A style of progress report used on the Chicago, Indiana & Southern Ry. was designed to show the percentage of work rather than quantities. The sheet had a number of columns headed: Earth bank, earth cut, rock cut, steel bridge, piers and abutments, concrete arch, pipe culvert, trestle, ties delivered, rail delivered, track laid, fences built, etc. This was ruled horizontally with a column of percentages (0 at bottom to 100 at top). A separate color was used for each month, and the columns were colored to show progress. This showed graphically the relative progress of the various parts of the work. The system might be adapted to maintenance and improvement work.

Correspondence.—Communications from superior officers should receive prompt and careful attention. The replies should be definite and concise. The letters should be filed for reference, together with copies of the replies.

Instruction Books.—The work of the roadmasters and section foremen, who are the men in actual charge of the track, carries a considerable responsibility. The most thorough means should be taken, therefore, to keep these men fully informed as to their duties. Books of instructions and rules for this purpose are in use on many roads. In introducing this plan, the books should at first be small and inexpensive pamphlets. After they have been in service for a sufficient time, improvements may be made so as to embody the best results of actual experience. A book can then be made up for permanent use. The matter should be clearly and concisely written, so as to be easily understood and to leave little chance for misunderstanding. The char

acter of the instructions and regulations has been outlined under "Organization." The book would include the rules and instructions governing roadmasters, section foremen, work-train conductors, extra-gang foremen, and foremen of the bridge and building department. It would have tables of curve elevations and ordinates for bending rails, etc., and bills of switch timbers. The illustrations would include roadbed cross-sections, methods of piling ties, turnout diagrams, rail joints, and similar details. They should preferably be on the pages of the book, or on sheets folded only once or twice. Large folded sheets are awkward to handle and are soon torn.

Requisitions.—One of the troublesome details is the handling of requisitions for supplies. Requisitions for ties and such material are not infrequently disallowed or cut down by an official who has no idea of the actual requirements.

DAILY RECORD OF TIME FOR

NAME	CHECK NO.	OCCUPATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Fig. 246.—Time Book;

He may think that requisitions are too large, or he may entertain the erroneous impression that every dollar cut from a requisition is a dollar saved to the company. Officers with authority of this kind should realize the economic relations between expenditures and the results obtained therefrom. The arbitrary cutting of requisitions is discouraging to men who have prepared them carefully with a view to actual needs, and the practice will result in careless estimates, or in requisitions purposely made excessive so as to meet requirements even when reduced. The roadmaster, engineer, or superintendent should inform himself as to financial and business conditions. He should prepare his estimates or requisitions with these conditions in view, and be prepared to show that they are reasonable and necessary. On the other hand, the superior officers should realize the economic relations between expenditures and results, and should recognize that the men in charge are in better position to know the needs for the proper maintenance and operation of the road. They should at least consult with them before making changes, and may then hold them strictly accountable or responsible. A careful system is required for the handling of requisitions in order that exact record may be kept of the materials, their cost and disposal. Special blank forms are generally used, and are sent to the head of the department. For material in small quantities or needed at once, and for which the regular procedure would be a red-tape obstruction, the order may be sent direct by the roadmaster to the storekeeper (or other official); he uses a special form and sends a duplicate of this to the engineer to provide for proper accounting. Foremen make requisitions monthly, except for special requirements; in such case, the roadmaster fills the order from his own store or makes a direct requisition upon the store department. All superior officers receiving requisitions should examine them to determine if they are necessary and reasonable.

Time Books.

Each section foreman has a time book in which he enters up the hours worked and the work done each day. These daily reports are of great importance,

as upon them is based the system of accounting and the distribution of expenses. In view of the limited education of the men, the time book should be as simple as possible, as already noted. Few railways consider it advisable to require the men to make a detailed analysis of the work. A new book is issued to each foreman every month, the old book being sent to the roadmaster at the end of the month. The book should be of convenient form to be carried in the pocket, and the foreman should have it always with him when on duty, in order that it may be examined by the roadmaster at any time. He should enter the records every day, while on the work. This original book should form the official report, being sent each month to the roadmaster. On some roads, however, the foreman copies his entries into a clean book. The book should provide for the record of the name of each man in the gang, the time worked

MONTH OF______________, 19__

21	22	23	24	25	26	27	28	29	30	31	TOTAL HOURS	RATE		AMOUNT	DEDUCTIONS			AMOUNT PAYABLE	PAYABLE AT
												Month	Hour		For	In Favor of	Amount		

Pittsburg & Lake Erie Ry.

by each daily, the work performed daily, and a summary or classification of the work done during the month. A system of daily reports has been tried, the purpose of which is to relieve the section foreman from the work of making up his book each month. The daily time sheet shows the total number of men, the total hours of work, the hours spent on different items of work, and the amount of work done (number of ties laid, length of track surfaced, etc.). For this method of reporting, the roadmaster's clerk is trained in the accounting system; he enters up these daily reports and prepares the monthly pay rolls and statements of labor and work. A traveling auditor would supervise the work of these clerks.

The Pittsburg & Lake Erie Ry. uses a time book $8\frac{1}{2} \times 5$ ins., bound at the narrow end, and having stiff-paper covers. Three double pages are arranged

DAILY DISTRIBUTION OF LABOR

DAY	KIND OF WORK AND WHERE DONE	HOURS	RATE	AMOUNT
1				

Fig. 247.—Report of Distribution of Labor; Pittsburg & Lake Erie Ry.

as in Fig. 246, with 16 horizontal lines; the bottom line is for totals. The foreman enters his own name at the top, and takes a line for each man; the man's check number and occupation are then shown. In the column for each day is shown the time worked by each man, and the total for the day is entered at the bottom of the page. At the end of the month is shown the total time worked by each man, with his rate of pay, and the amount of wages due. The deductions are for board bills (sent with the book), hospital or relief funds, etc. The net amount payable to the man is then shown. The next 16 pages

are for the daily distribution of labor; each page is for two days, with 18 lines to a day. They are ruled as shown in Fig. 247. The next six pages are ruled in the same way, but are for a monthly summary of the daily records, showing a classification of the labor. The first column shows the account to which each item is assigned (see Table No. 44). The printed classification (given in two columns in Table No. 42) fills less than two pages, the remainder being left blank for additional classification and special items. At the right are columns for "hours," "rate" and "amount," as in Fig. 247.

TABLE NO. 42.—SUMMARY OF CLASSIFICATION OF LABOR; P. & L. E. RY.

Acct. No.	Kind of Work Done.
1	Superintendence.
2	Ballast: Loading and unloading.
6	Ballast: Applying.
6	Ties, cross, switch and bridge: Loading and unloading.
6	Ties, cross and switch: Applying.
6	Ties, cross and switch: Respacing.
6	Rails: Loading, unloading and handling.
6	Rails: Applying.
6	Other track material: Loading, unloading and handling.
6	Other track material: Applying.
6	Track repairs: Surfacing, lining and gaging.
6	Track repairs: Tightening bolts and spikes.
6	Roadway: Cutting grass and weeds.
6	Roadway: Ditches, constructing and cleaning.
6	Roadway: Banks, widening, sloping and sodding.
..	Roadway. Retaining walls to protect roadbed.
6	Roadway: Slides, removing and repairing washouts.
6	Scrap handling: Track scrap, including scrap rail.
38	Scrap handling: Car scrap.
6	Watchmen: Track, cuts and banks.
8	Watchmen: Tunnels.
9	Watchmen: Bridge, except at drawbridges.
97	Watchmen: Street crossing and gatemen.
98	Watchmen: Drawbridge.
9	Bridges and culverts: Repairing or cleaning.
7	Snow and ice: Removing from tracks.
7	Snow and ice: Removing from tracks (overtime).
68	Snow and ice: Removing from station platforms and walks.
7	Snow fences: Placing and removing.
12	Snow fences: Building and repairing.
11	Fences, cattleguards and road crossings: Building and repairing.
11	Signs: Repairing.
13	Signals and interlockings: Repairs and renewals.
14	Telegraph and telephone lines: Repairs and renewals.
16	Station grounds: Repairing walks, driveways and fences.
16	Station grounds: Cleaning and cutting grass.
16	Stock yards: Repairing.
18	Tools: Repairing and sharpening.
19	Cars, work equipment: Repairing.
38	Cars, freight: Repairing.
95	Cars, freight: Cleaning.
68	Cars: Transferring freight.
68	Stations: Cleaning; handling baggage and freight.
72	Stations: Handling fuel.
68	Lampman: Station lamps.
75	Lampman: Switch and yard signal and interlocking lamps.
96	Lampman: Block and signal lamps.
87	Handling ashes: Ash pits and roundhouses.
79 & 88	Fuel for locomotives: Handling.
16	Water stations and track tanks: Repairing.
80 & 89	Water stations: Pumping and cleaning tanks.
80 & 89	Water stations: Handling fuel.
99	Wrecks, clearing: Except work-train wrecks.

The Illinois Central Ry. uses for the time roll and distribution of labor a book which gives a sealed carbon copy of all entries. This provides against alterations and erasures of original entries. It is required that all unfilled spaces must be cancelled each day, so that there is no opportunity to date back a new man in order to give him pay to which he is not entitled. The roadmasters examine the books frequently, and special time inspectors travel over the line to check the number of men in each section gang with the number in the foreman's time book. On the 27th of each month, the books are sent to the roadmaster. He examines them and uses them in preparing his own report, and then forwards the original books (with his report) to the auditor's office. The pay rolls are then compared with the work shown in the books, and the books are returned to the roadmaster. The book is $8\frac{1}{2}\times 9$ ins.; arranged to fold to $5\frac{1}{2}\times 9$ ins., so that it can be carried conveniently in a case for the pocket. The first double page is in duplicate, with a carbon sheet between, and the edges of the two sheets are pasted together, so that the

duplicate is inaccessible. This part of the book is ruled as shown in Fig. 248. There are 20 lines for names, but under the date headings the space for each name is subdivided by a horizontal line, making two spaces. These are for recording the morning and afternoon time.

The time is entered four times each day. When a man reports for duty in the morning, a dot is made in the upper space, and at noon the number of hours worked is entered in this space. When he reports after dinner, a dot is made in the lower space, and when the day's work is completed the number of hours worked is entered in this space. If a man does not report, a heavy cross is made in the space opposite his name. If he leaves and is given an order for his time, the foreman enters "Time given" in the column for remarks, and cancels each space opposite the name by a horizontal line. When the number of men is such that the 20 lines are not filled, the empty spaces below the last name are cancelled by drawing a heavy line immediately above the space for "Total." This must be done immediately after dinner (1 p.m.). Thus Fig. 248 shows that on the 28th, John Brown, foreman, worked five hours before dinner and five hours after dinner; James Lincoln, laborer, did not work in the morning, but worked four hours in the afternoon. Amos Garfield worked only two days. A roadmaster or inspector examining the book in the field will note if the number of dots is the same as the number of men at work. The column must be added up each day, and the total entered at the foot. For overtime (after 6 p.m.) the hours must be entered after the morning record, with explanation on a special page which is divided horizontally into three parts for explanations of "New work," "Overtime," and "Errors." If an entry is incorrectly made, by mistake, it cannot be erased, but must be explained under "Errors." The system is less complicated than might seem from the description, and is easily understood by the foremen.

The distribution of labor is entered on a double page having date rulings as before, but with a classification of labor at the left and a list of accounts chargeable at the right, as in Fig. 249. This is not in duplicate. The next two pages are ruled for explanations as to work done under certain specified items of the classification. Blank lines provide for work which cannot be entered properly against any of the printed items. Another double page is then ruled like the time roll, but is for teamsters; this gives the name of each man and number of teams. The last page is for the use of the accountant, giving detail of charges to "Construction," "Additions and betterments," and "Sundry distribution." On the inside of the cover is a table of wages for various rates per hour and per day, giving the amount due for various numbers of hours at each of the several rates. This is for a 10-hour day. The time book for the bridge-and-building gangs is similar to that of the section gangs. The time sheet is followed by 20 double pages for report of labor performed. These are ruled in the same way, except that the column for "deductions" is omitted, while in place of the two columns for name and occupation, there is a wide column for the foreman's description of work performed.

All time books are numbered. The division officers are required to keep a record of the number of the book delivered to each foreman, and the foremen are not allowed to keep extra books on hand. This provides a check upon the books used and returned. The auditor of disbursements also keeps a record of the number of the books sent to each division, and the division officers are required to make an explanation as to books that are not returned.

TIME ROLL **Section No.**

	NAME	OCCUPATION.		28	29	30	31	1	2	3	4
1	John Brown	Foreman	A.M.	.5	.5						
			P.M.	.5	.5						
2	James Lincoln	Laborer	A.M.	X	.5						
			P.M.	.4	.5						
3	Amos Garfield	Laborer	A.M.	.5	.5	–	–	–	–	–	–
			P.M.	.5	.5	–	–	–	–	–	–
19			A.M.								
			P.M.								
20			A.M.								
			P.M.	—	—						
	TOTAL.			24	30						

Fig. 248.—Time Book:

CHARGE TO ACCOUNT NUMBER.		28.
4.	Unloading........ballast.	....
9.	Ditching and embanking.	....
10.	Putting........ballast in track.	....
11.	Laying ties in track.	....
11.	Loading and distributing ties.	....
12.	Laying and surfacing rails in main track.	....
12.	Laying and surfacing rails in sidetracks.	....
12.	Loading and distributing rails for renewals.	....
13.	Removing grass or weeds from track or right-of-way.	....
14.	Putting in frogs and switches.	....
14.	Taking up sidings. (Give location.).	....
14.	Other work on tracks.	....
15.	Repairs to tracks, account wrecks or washouts.	....
17.	Distributing and putting up snow fences.	....
17.	Cleaning snow and ice from tracks.	....
19–20.	Cleaning under or repairs to bridges. (Give number.).	....
21.	Roadways under or bridges over highways.	....
22.	Highway grade crossings.	....
23.	Repairs to cattleguards and signs.	....
24.	Repairs to right-of-way fences.	....
26–27–28.	Repairs to interlocking, block or other signals. (Give location.).	....
29.	Repairs of telegraph.	....
30–31.	Repairs to buildings. (Give name and location.).	....
32.	Repairs to scales.	....
33.	Repairs to fuel stations.	....
34.	Repairs to water stations.	....
35.	Cleaning station grounds.	....
36.	Cleaning shop grounds.	....
37.	Repairs to docks and wharves.	....
39–40–41, 51 to 65	Repairs to cars or locomotives. (Give number.).	....
92.	Cleaning stock pens or chutes. (Give location.).	....
92.	Tending switch lamps. (Give location.).	....
92.	Cleaning station platforms.	....
92.	Cleaning snow and ice from station platforms.	....
92.	Transferring or rearranging freight in transit.	....
105–118–119.	Pumping water.	....
130.	Cleaning stock cars. (Give location.).	....
135.	Clearing wrecks.	....
145.	Burying stock.	....
	Grading for new siding. (Give detail.).	....
	Other work on new sidings. (Give detail.).	....
	Handling company coal, wood or ice. (Give detail.).	....
	Cook's wages.	....

Fig. 249.—Distribution of

*___Division. Month ending 27th of________________190_*

18	19	20	21	22	23	24	25	26	27	TOTAL TIME	RATE OF PAY Per Month	RATE OF PAY Per Hour	AMOUNT OF WAGES.	DEDUCTIONS.	REMARKS
–	–	–	–	–	–	–	–	–	–						
–	–	–	–	–	–	–	–	–	–	20					Time given

Illinois Central Ry.

29.	26.	27.	TOTAL TIME.	ACCOUNT NUMBER.	ACCOUNTS CHARGEABLE.	District No. ....
				2	Superintendence—Salaries	
				4	Ballast	
				9	Ditching and embanking	
				10	Applying ballast	
				11	Applying ties	
				12	Applying rails	
				13	Removal of grass, weeds, etc.	
				14	General repairs of roadway and tracks	
				15	Extraordinary repr. of roadbed and tracks	
				16	Water-front protection	
				17	Removal of snow, sand and ice	
				18	Tunnels	
				19	Bridges, trestles, etc.—timber	
				20	Bridges, trestles, etc.—permanent	
				21	Over and under grade crossings	
				22	Highway grade crossings	
				23	Cattleguards and signs	
				24	Right-of-way fences	
				25	Snow and sand fences and snow-sheds	
				26	Interlocking plants	
				27	Block signals	
				28	Other signals	
				29	Telegraph and telephone lines	
				30	Shops, engine houses and turntables	
				31	Stations, office and miscellaneous buildings	
				32	Scales	
				33	Fuel stations	
				34	Water stations	
				35	Station grounds	
				36	Shop grounds	
				37	Docks and wharves	
				{39–40–41 / 51 to 65}	R. & R. of..........loco. or cars	
				92	Other station services	
				105–118–119	Water supply	
				135	Clearing wrecks	
				145	Damage to stock on right-of-way	
					Construction. (Detailed on page 10.)	
					Sundry distributions. (Detailed on p. 10)	
					Additions and betterments. " " "	

Labor; Illinois Central Ry.

The time book of the Chicago & Northwestern Ry. is peculiar in requiring the foreman to make an elaborate distribution of time and labor for each man each day. There is a double page for each man, ruled as in Fig. 250. The book is 8¾×9½ ins., with stiff-paper covers, and five double pages. A similar book is used for work trains and gravel pits. On the second page of the cover are detailed instructions to track foremen, and these (in condensed form) are given below. On the third page of the cover is a form for recording the names of employees who have left during the month; the cause of leaving and other particulars are given. The record cards of these men (sent by the foreman to

WORK PERFORMED IN THE

BY...

		MAINTENANCE-OF-WAY AND STRUCTURES.																	
		REPAIRS OF ROADWAY AND TRACK.											Repairs of Bridges and Culverts.						
Date.	Total Time Worked.	Laying Rails.	Laying Ties.	General Repairs of Track.	Ballasting.	Filling Bridges, Trestles and Culverts.	Cleaning Out Ditches.	Clearing Track of Snow and Cutting Weeds.	Track Watchmen.	Freshet Repairs.	Repairs of Interlocking Plants.	Repairs of Block Signals.	General Repairs of Bridges and Culverts.	Bridge Watchmen.	Repairs of Fences, Road Crossings, Signs and Cattle-guards.	Maintaining Telegraph.	Laborers at Stations.	Flagmen.	Fuel for Locomotives.
1																			
2																			
3																			
30																			
31																			
Total No. of Hours																			
Total Wages																			

Fig. 250.—Time Book with Distribution

the division superintendent for each new employee) can then be removed from the file.

Instructions to Foremen for Keeping Time and Distributing Track Labor; Chicago & Northwestern Ry.

At the close of each day's work the total number of hours worked by the foreman and each laborer should be entered in the column headed "Total time worked," a separate page being used for each man. Then under the proper headings in the columns following should be entered the number of hours chargeable to each account. At the close of the month, each column should be added, the totals being inserted in the spaces opposite the words, "Total number of hours." The sum of the distribution columns should equal the footing of the column headed "Total time worked."

As soon as the last day's time is entered each month, and the book footed, it should be certified by the foreman and forwarded by first mail to the roadmaster. The latter will carefully examine it to see that the entries are correct in accordance with his knowledge of the work done. He will certify it, and forward it to the division superintendent for use in making the pay roll.

Maintenance of Way and Structures.—This is chargeable with the cost of all work necessary to keep the property in as good condition as when first built. If, for instance, a road crossing is worn out, the whole cost of renewing it with one practically the same as the old one was when first built should be charged to this account. But if a larger or better crossing should be put in, then only that part of the expense which would be required to replace the old

MONTH OF ...., 190...

OCCUPATION......................... RATE................ PER...

Clearing Wrecks.	Loading Cinders at Cinder Pits.	Unload'g Fuel into Storage.		Construction.															Remarks.
													Sidings						
		Coal.	Wood.	Tracklaying.	Ballasting.	Rectifying Grades.	Changing and Straightening Line.	Widening Embankments and Cuts.	Filling Bridges, Trestles and Culverts.	Ditching.	Fences.	Road Crossings and Signs.	Grading.	Tracklaying.	Ballasting.		Block and Other Signals.	Interlocking Switches.	

of Labor; Chicago & Northwestern Ry.

crossing with one like it is chargeable to this account. The excess, or cost of the improvement, is chargeable to Construction.

Laying Rails.—Time used in taking up and disposing of old rails; and unloading, handling, and laying new rails to replace those taken up.

Laying Ties.—Time used in taking up and disposing of old ties; and unloading, handling, and laying new ties to replace those taken up.

General Repairs of Track.—Time used in repairing and renewing frogs, switches, switchstands, rail braces, tie-plates, track fastenings, etc.; picking up and loading miscellaneous scrap material along the roadway; inspecting track, repairing and renewing retaining walls, etc., made to protect track, and taking up old sidetracks. The expense of repairing and renewing snowsheds and snow-fences (when not also right-of-way fences) must be entered here.

Ballasting.—Time consumed in preparing, distributing, and renewing ballast, in order to put the track in as good order as when originally ballasted.

Filling Bridges, Trestles, and Culverts.—Time used in filling with earth work, when the cost of such work is not in excess of the cost of replacing the structure. The number and location of the structure should be given under "Remarks."

Cleaning out Ditches.—Time used in opening, clearing, and repairing ditches in order to make them as good as when first made.

Clearing Track of Snow and Cutting Weeds.—Time used in clearing snow, ice, weeds, brush, and grass from the track; and mowing and burning weeds, brush and grass inside of right-of-way fences.

Track Watchmen.—Time of men engaged as track watchmen and flagmen while repairs of track are in progress, rendered necessary by such repairs.

Freshet Repairs.—Time used in repairing damages to roadway and track caused by freshets and washouts.

Sidetracks.—Time used in repairing sidetracks should be included under "Repairs of roadway and track," under the appropriate headings.

Repairs of Interlocking Plants.—Time consumed in repairing interlocking plants, including tower buildings, and switches and signals operated by the plant. The name and location should be given under "Remarks."

Repairs of Block Signals.—Time used in repairing train-order, distant, and block signals, including tower buildings. The name and location should be given in the "Remarks" column.

General Repairs of Bridges and Culverts.—In this column should be entered time used in repairing; also time of men engaged as watchmen and flagmen while repairs of bridges and culverts are in progress, rendered necessary by such repairs. The number and location of the structure should be given under "Remarks." The cost of repairing the track (rails, ties, guard rails, fastenings, etc.) over bridges, trestles, and culverts should not be charged to this account, but should be charged to "Repairs of roadway and track," under the appropriate headings.

Bridge Watchmen.—Time of bridge watchmen who are regularly employed as such, and not required on account of special repairs being made.

Repairs of Fences, Road Crossings, Signs, and Cattleguards.—Time in repairing right-of-way fences, road crossings (including the roadways and streets thereon), track and crossing signs, and cattleguards (or rebuilding them if necessary), in order to render them as good as when first built.

Maintaining Telegraph.—Time used in repairing or looking after telegraph and telephone lines, resetting poles, etc.

Laborers at Stations.—Time assisting station agent in loading or unloading freight, cleaning or caring for stations and station grounds, cleaning stock yards, cleaning snow and ice from station platforms, sidewalks, etc., and caring for switch lamps. In each case the name of the station and nature of the work done should be given.

Flagmen.—Time of men while engaged as flagmen at public crossings, except when rendered necessary by repairs to track or similar special work.

Fuel for Locomotives.—Time consumed in coaling engines, filling coal buckets or chutes to deliver coal to locomotives.

Clearing Wrecks.—Time of men employed in clearing up wrecked cars or locomotives, including all time consumed in reloading cars, transferring passengers and baggage, or other necessary work resulting from a wreck, such as building temporary tracks around wrecks, etc. The cost of repairing damage to the track caused by a wreck should not be charged to this account, but should be entered under the appropriate headings under "Repairs of roadway and track."

Loading Cinders at Cinder Pits.—Time used in loading cinders at cinder pits, no matter for what purpose same are to be used.

Unloading Fuel Into Storage.—Time unloading coal from cars into coal houses or on the ground (and loading or unloading wood from or into cars), when same is to be stored, no matter for what purpose it is to be used.

Construction.—This is chargeable with the expense of building entirely new or additional pieces of work; such as constructing a new crossing, building a fence where the right-of-way was not previously fenced, or laying tiling or making ditches where there was none before. It is also chargeable with the expense of enlarging or improving any existing facilities or structures.

If the length of a crossing is increased, or if a fence has a fifth wire added, the cost of such extension or additional work is chargeable to Construction. The idea is to charge Construction (under the proper account) with the added expense which the company may incur in the improvement of its property. Any additional expense which increases the value of the property (excepting that which merely restores it to its original condition when new) is chargeable to Construction.

Tracklaying.—Time used in putting in rail braces, tie-plates, etc., on main-line tracks where there were none before.

Ballasting.—Time used in ballasting main-line tracks which were not previously ballasted. Also the increased cost (if any) of labor required in replacing one kind of ballast with a better kind, over the cost of the labor required to replace the old ballast with same kind.

Rectifying Grades.—Time used in cutting down grades, changing grade levels, or filling sags, when such work is a change from the grade of the line as originally constructed and not repairing wear and tear due to operation.

Changing and Straightening Line.—Time used in changing and straightening the line of road, eliminating curves, etc.

Widening Embankments and Cuts.—Time used in widening them beyond the original width.

Filling Bridges, Trestles, and Culverts.—Time used in filling with earthwork when such outlay is in excess of the amount which would be required to replace the structure with another like it. The number and location of the structure should be given. (The cost of the filling up to the amount required to replace the structure with another like it should be charged to the proper account under "Maintenance of Way and Structures.")

Ditching.—Time used in laying additional tiling, making new ditches, and deepening or widening old ditches beyond the depth or width when originally made. (The cost of reopening old ditches or digging out dirt, etc., deposited in such ditches since their construction, should be charged to the proper account under "Maintenance of Way and Structures.")

Fences.—Time used in building right-of-way and snow fences where there were none before. When a fence is improved by adding more wires or more posts, the time used on account of such work should be charged to this account.

Road Crossings and Signs.—Time used in putting in additional road crossings, including roadways and streets thereon, farm gates at new openings, track and crossing signs, and cattleguards; also any labor spent in improving such structures. The location and name or number of each crossing should be given under "Remarks."

Sidings.—Time used in building new sidetracks, crossover tracks, etc., and extending or improving old ones, including grading, ballasting, putting in switches and connections with the main line, and any other expenses connected with the laying of a siding. The time should be entered under the proper headings: "Grading," "Tracklaying," "Ballasting," etc. In the column headed "Remarks" should be given the name and location of each siding, and the authority for doing the work.

Block and Other Signals.—Time used in putting in additional train-order, distant, and block signals (including tower buildings), or improving old ones. The name and location of each block station, etc., should be given in "Remarks."

Interlocking Switches.—Time used in putting in additional interlocking switches and tower buildings connected therewith; also cost of additions to or improvements of existing plants. The name and location of each plant must be given in "Remarks."

Blank Columns.—In these should be entered all labor expended which is not properly chargeable under any of the headings preceding. A full description of the work should be given in "Remarks."

Accounting and Maintenance-of-Way Expenses.

The expenditures for maintenance-of-way and structures represent from 12 to 25% of the operating expenses of a railway, but there is very little reliable information as to the cost of the various classes of work included. In all

accounting for engineering and construction work, it is important that unit costs should be determined or made available, but this feature is to a great degree neglected in maintenance-of-way. The annual reports of railway companies form the most available source of information, but these give merely totals and lump sums for the entire mileage, so that no definite deductions or comparisons can be made. Division reports as a rule do not enter into greater detail. The system of accounting as finally compiled is generally arranged to meet the requirements of the Interstate Commerce Commission; there are certain arbitrary classifications, and there is no separation of labor and material. On very few railways is information as to itemized expenses or unit cost available even to engineers in the maintenance department. This was shown by an investigation made by the author in 1905, in seeking to obtain information of this kind for compilation and analysis. ("Engineering News," July 27, 1905.) Several engineers stated that they realized the desirability of such information, but that the systems of accounting used by their roads did not provide for this, and they had not the time or the opportunity to develop or introduce such a system as would produce the desired results.

The only method, as a rule, is to take the total amounts given for the few general classifications and divide these by the mileage, so as to obtain some very rough approximate figures of cost per mile. The annual reports of railway companies give among the operating expenses the expenditures for maintenance-of-way and structures. Sometimes these are subdivided into rail renewals, tie renewals, roadway repairs, etc. But there is nothing to show the amount of work. Rail renewals may be done on 50 miles of a 100-mile division or a 1,000-mile railway. The cost of this work divided by 100 or 1,000 would give an absolutely useless (and misleading) figure of average cost of rail renewals per mile. On some railways it is possible to determine these costs by wading through files of detail reports, but this is rarely done, and as a rule the information is not obtainable in any way. It is very desirable, however, that summaries or compilations of the time-book figures should be made available as a basis for estimating unit costs.

The reports of the Illinois Central Ry. and the Atchison, Topeka & Santa Fé Ry. give the annual expenditures for maintenance-of-way and structures per mile of road for a term of years. These range from $1,127 to $1,448 on the first, and from $782 to $1,194 on the second road, but it will readily be seen that the figures are practically valueless in that they do not show the amount or character of the work covered. The cost of rail and tie renewals per mile of track on 20 railways also, has been found to range from $19 to $143 for the former, and from $66 to $225 for the latter. On the Hocking Valley Ry. the ratios of some items of the maintenance expenses to the total operating expenses in 1904 were as follows: Repairs of roadway, 4.84%; rail renewals, 1.15%; tie renewals, 1.69%; repairs and renewals of bridges and culverts, 1.09%; repairs and renewals of fences, crossings, and cattleguards, 0.20%; repairs and renewals of buildings and fixtures, 1.23%; total, 10.31%. A few reports list such items as quantities of rails, ties and ballast laid.

As already noted, the accounts of the maintenance-of-way department are based usually upon the requirements of the auditor. On the Pennsylvania Lines, these accounts are kept under the arrangement shown in Table No. 43. The auditor cares only for the general heads, while the division officers keep

their accounts under the subheads. It will be seen that the accounts are not kept in such a way as to give unit costs.

The lack of complete and uniform records of the cost of various items of work is a drawback to the economical administration of the roadway department. In an address delivered before the Roadmasters' Association in 1897, the author pointed out that if statistics were kept of the cost of the various items of work on the track, they would furnish very valuable information. As a matter of fact, there is great uncertainty both as to the cost of work and as to the amount of labor involved in the work. The importance of this matter may be recognized when it is understood that a roadmaster may have charge of the expenditure of large sums of money, as already explained under "Organization" and in the introductory chapter. The matter has also an important relation to the economy of maintenance-of-way and the general operation of the road. If properly planned and carried out for a few years the records may show that expensive ties (including cost of preservative processes and tie-plates) may be really more economical than cheaper ties, by reason of their greater life, thus giving a lower cost per year. They may also show, in the

TABLE NO. 43.—DISTRIBUTION OF MAINTENANCE-OF-WAY ACCOUNTS; PENNSYLVANIA LINES.

1. Engineering and superintendence: A, Pay of officers; B, Pay of clerks and attendants; C, Office and traveling expenses.
2. Track maintenance.
3. Applying track material: A, Rails; B, Ties; C, Ballast.
4. Roadway clearing and policing: A, Care of roadbed; B, General cleaning; C, Snow and ice; D, Patroling and watching; E, Refuse material.
5. Ballast. 6. Rails. 7. Ties.
8. Track appliances: A, Rail fastenings; B, Frogs and switches.
9. Roadway tools.
10. Other roadway maintenance: A, Tunnels; B, Viaducts; C, New tracks; D, Bank protection; E, Filling; F, Other expenses.
11. Bridges and culverts: A, Structures; B, Watchmen and supplies; C, Other expenses.
12. Buildings and grounds: A, Buildings; B, Furniture and fixtures; C, Incidental building expenses; D, Machinery and fixtures; E, Other expenses; F, Driveways and grounds.
13. Docks and wharves: A, Repairs; B, Dredging and cleaning.
14. Interlocking plants and signals: A, Interlocking plants; B, Automatic signals; C, Other expenses.
15. Fences, road crossings and signs: A, Highway grade crossings; B, Other crossings; C, Fences; D, Other signs.
16. Telegraph and telephone lines. 17. Electric traction lines.
18. Stationery and printing. 19. Insurance.. 20. Incidentals.

general cost per mile of track, the false economy of laying new rails on poor ties and ballast, the same rails showing a shorter life and a greater total cost for maintenance of track than when laid as part of a good track.

These are questions of railway economics, for it must be understood that merely cutting down expenditures is not necessarily an economy. It may be a wiser policy to make a large outlay at one time, and thus reduce the cost of maintenance for several years, than to distribute the expenditure in small sums, with the result of having a continual high charge for maintenance. The work of keeping such records might seem somewhat complicated at first, but after a few years it would become crystallized into a uniform standard practice, so that extremely valuable records could be kept with very little trouble or cost. If railway managing officers more generally realized the importance of the expenditures on track, both directly as cash expenditures and indirectly in their influence upon traffic and other expenses, they would demand a more detailed accounting of these expenditures and their results.

It is important that the cost of labor and materials should be separated, but in most cases this is not done. The plan outlined by Mr. Marshall M.

Kirkman, Vice-President of the Chicago & Northwestern Ry., in his pamphlet on "The Track Accounts of Railways," is to have the final records attained in two distribution books, one for labor and the other for material. These are posted up by the superintendent monthly from the foremen's books, and show all track expenditures, and the accounts to which such expenditures are properly chargeable. At the general office a "track material" account is kept with each division superintendent. In the superintendent's book the average cost per mile for repairs of track and roadway is obtained by summing up the total number of hours worked on each subdivision, and taking a full day's work for each man for the entire month. On the Minnesota & Dakota division (1,300 miles), the average maintenance-of-way expense per mile in 1903–04 was $285 for labor and $180 for material, or $465 in all. The classification is so broad and the mileage included so great that the figures are indefinite in the absence of information as to work done, labor employed or materials used. On the Pittsburg & Lake Erie Ry., the distribution of labor is made monthly for each division according to the list in Table No. 44. This list is

TABLE NO. 44.—DISTRIBUTION OF PAY-ROLL LABOR; PITTSBURG & LAKE ERIE RY.

A. Maintenance of Way and Structures.

1. Superintendence.
2. Ballast.
6. Roadway and track.
7. Removal of snow and ice.
8. Tunnels.
9. Bridges, trestles and culverts.
10. Over and undergrade crossings.
11. Grade crossings, fences, cattleguards and signs.
13. Signals and interlocking plants.
14. Telegraph and telephone lines.
16. Buildings, fixtures and grounds.
18. Roadway, tools and supplies.
19. Work equipment: Repairs.
26. Maintaining joint track, yards and other facilities, Dr.

B. Maintenance of Equipment.

28. Superintendence.
35. Passenger cars: Repairs.
38. Freight cars: Repairs..
47. Shop machinery and tools.

C. Transportation Expenses.

66. Superintendence.
68. Station employees.
72. Station supplies and expenses.
75. Yard switch and signal tenders (lampmen).
78. Engine-house expenses (yard).
79. Fuel for yard locomotives.
80. Water for yard locomotives.
87. Engine-house expenses (road).
88. Fuel for road locomotives.
89. Water for road locomotives.
91. Other supplies for road locomotives.
95. Train supplies and expenses.
96. Interlockers, block and other signals (lampmen).
97. Crossing flagmen and gatemen.
99. Clearing wrecks.
108. Damage to property.
106. Damage to stock on right-of-way.

D. General Expenses.

115. General office supplies and expenses.

printed in one column at the left of a sheet 8×14 ins., attached to which is a blank sheet for "Work authorized." The amounts are entered at the right of each sheet. This list may be compared with the time-book classification of work in Table No. 42.

During construction and maintenance, careful notes should be made and records kept and tabulated to show the work done, time occupied, materials used, items of cost, etc. The regular reports should show the number of men engaged on each particular item and class of work, and the character and amount of materials used. All work of this kind tends toward the improvement of work and methods, since it puts figures on record and enables comparisons to be made, and the relations between work, expenditure, and results to be comprehended. Proper financial accounts of all expenditures for maintenance and renewals and betterments should also be made. In the annual estimates, some railways allow to each division a certain amount for track work, but the appropriation for betterments or construction should be entirely separate from that for maintenance. The cost of additions and betterments is

very generally charged to operating expenses in this country, although some railways charge it to capital.

Accounts should be kept for additions and betterments (or improvements), separate from maintenance, and this practice is becoming more general. The system should require an estimate of cost and formal authority for the appropriation or expenditure for each piece of work. Ledger accounts with individual pieces of work are thus necessary, in order to show the detail, total, comparative, and unit cost. Forms for the estimate and authority have been adopted by the American Railway Engineering Association (Proceedings, 1907 and 1908). Under the system recommended, the ledger accounts include five steps: 1, Preparation of the estimate; 2, Authorization; 3, Appropriation; 4, Monthly report of expenditure; 5, Ledger record of total cost of the completed work. A general manager (or vice-president) will request the chief engineer to make a study of and estimate for a proposed improvement. The chief engineer will submit his statement and estimate on the proper form; if approved by the general manager it will go to the president and board of directors. On their approval, the manager will issue to the engineer a form authorizing the improvement. This will show the total sum appropriated, a brief description of the work, and whether it is classed as construction, additions, renewals, etc. Requisitions against this appropriation will be made as required, and will show the relations between the appropriation and the expenditures. There will also be a monthly report of expenditures. At the head of this will be the number of the authorization, the amount of the appropriation, description of the work, and date of commencement and completion. Under this will be columns for the expenditure of the month, previous expenditure, total expenditure to date, and estimated expenditure for the next month, etc. The form of this report is a sheet 8×14 ins., with the headings across the 14-in. width. The ledger account serves as a final statement and a permanent record of cost. It should show the character and quantity of materials used, with their cost, and the quantity of labor performed. This will enable unit costs to be determined, which is an important feature.

This system can be adapted to the work of the maintenance-of-way department, and the Pittsburg & Lake Erie Ry. uses it for all new work. The records of such accounts may be kept conveniently on the card-index method. Each piece of work has a number, and all papers and correspondence relating to it are filed under the same number in suitable cases. In the office of the engineer of the Southern Pacific Ry. a set of cards 5×3 ins. is used to record in condensed form the essential particulars regarding requisitions for new work and the progress of this work. The requisitions are sent in to the engineer, and a card is taken for each. The character and purpose of the work, and its estimated cost, are written along the upper part of the card, and below this are columns showing the dates on which the card was sent to the several superior officers for their approval. The appropriation for the work is shown; also the dates of the authorization, commencement and completion of the work. At the bottom is a space for remarks. On the back of the card (and printed across the 3-in. width) are columns showing for each month the expenditures for labor and material, the total for the month, and the total from date of commencement. A number is assigned to each piece of work, and certain series of numbers are used for different classes of work, such as "Laying rails," "Building bridges," "Repairing stations," etc. Cards of different

colors indicate the different districts in which the works are located. The cards are filed by the numbers, and are indexed both by subjects and districts. With these cards (and additional plain ruled cards filed with them), full information as to cost and progress of work can be obtained at any time.

In regard to the classification of maintenance-of-way expenses and the distinction between repairs and improvements, Mr. W. G. Berg, Chief Engineer of the Lehigh Valley Ry., has advocated a general separation of these expenses into "repairs" and "improvements" (Proceedings of the American Railway Engineering Association, 1904). The repairs he divided as follows: 1, Current; 2, Contingent; 3, Special, and 4, Extraordinary repairs. The improvements he divided as follows: 1, Betterments, and 2, Additions. The work is classed in order of its necessity. Thus current repairs (under control of the division engineers and the roadmasters) must be carried on, whatever may be the financial conditions. In the same way, some betterments will be made even in time of financial stringency. But other classes of repairs can be temporarily deferred. The bulk of the betterments also (and more especially the additions) can be postponed indefinitely, even though this may involve increased operating expenses or a loss of revenue.

Accounting is sometimes thought to be a matter that does not require much attention from engineers. As a matter of fact it is very important that they should have proper records and proper distribution of the expenses on work entrusted to their care. It is important for the information of (and sometimes even the protection of) themselves and their superiors or employers. Railway engineers are apt to fail to realize the importance of an accounting system for their own work, and especially its important relation to the general business and accounts of the railway. In other words, they sometimes overlook the fact that their department is only one feature in the business of operating railways, and they need to give greater consideration to the financial relations of their work. It is not enough for an engineer to know (or for his superiors to believe) that he is competent and faithful. He should be able to demonstrate this at any time when his work may be called in question, or when it is necessary to support an estimate or opinion. For this reason he should give careful attention to the systems of records, reports and accounts for his work, whether it is in the line of construction, of general improvement, or of maintenance. It is probable that in the future more will be required of the engineer in recording and accounting for the expenditures on the work entrusted to his charge.

APPENDIX.

A REVIEW OF STANDARDS OF TRACK CONSTRUCTION ON AMERICAN RAILWAYS.

An investigation as to the standards of main-line track construction of American railways was made by the author in 1907–08, and the results are given in the accompanying tables, which were published in "Engineering News," June 4, 1908. The railways included represent those of the smaller class as well as the more important lines and railway systems. They have an aggregate length of 153,800 miles, of which 15,100 miles are in Canada (on two railways). The total railway system of the United States is approximately 225,000 miles, and about 66% of this total (nearly 140,000 miles) is represented by the railways for which information is given. The mileage of each railway is given as an indication of its importance. The figures have little bearing upon track conditions, as a railway of any length will include various kinds of track. The tables represent the character of track applied in new construction and in renewals. Of course a great mileage of lighter track exists on the railways mentioned; not only on their branches and secondary lines, but also on their main lines. The information (which was obtained through the courtesy of the engineers of the various railways) is very complete, but it must be remembered that the extent to which the standards are in actual use is an unknown and extremely variable quantity.

As to the weight of rail, since 1900 there has been a general raise in the "standard," which is of course the maximum. Of 40 railways, over 50% report an increase of 5 to 20 lbs. per yd. The form of section approved by the American Society of Civil Engineers is used very generally. Only a few roads report other sections, although it must be noted that these lines represent an extensive mileage. In regard to length of rails, there is a surprising unanimity in the adoption of 33-ft. rails. In 1900, only eight railways reported 33 ft., against 44 reporting 30 ft. as the standard length; one reported 30 and 60 ft. and another 30 and 45 ft. In 1908, 53 railways report a standard length of 33 ft.; only two report 30 ft., and four report both 30 ft. and 33 ft. No mention is now made of rails longer than 33 ft., which are evidently exceptional and used only in special cases. The 33-ft. rails eliminate 10% of the joints, and are practically no different from the 30-ft. rails as to handling and maintenance.

As to rail joints, the tendency is towards short splice bars with four bolts; 40 railways have bars from 24 to 28 ins. long, as compared with 12 having bars from 30 to 36 ins. long, and only four have bars from 38 and 44 ins. long. In regard to the number of bolts, 36 railways use four bolts, 19 use six bolts and 2 use both four-bolt and six-bolt splices. The bolt spacing is generally from 4 to 6 ins.; the minimum is 4 ins., while 7-in. and 8-in. spacing is used in a very few cases. The maximum is 9 ins., which is used on only two roads,

and is in each case for the outer bolts of a six-bolt joint with 40-in. and 44-in. angle bars. The bolts are $\frac{3}{4}$-in., $\frac{7}{8}$-in., and 1-in. diameter. On many roads a grip thread is used on both bolt and nut, the latter forming a lock nut and dispensing with the use of a separate nut lock. Nearly all of the railways lay their rails with broken joints; eight use square joints on tangents and broken joints on curves.

The old style of supported joint, with a single tie and short splice bars, is practically obsolete; it is used on parts of the Michigan Central Ry. and the Lake Shore & Michigan Southern Ry., with 23-in. and 24-in. bars respectively. The three-tie joint with long splice bars is used on a few roads, but is not the standard pattern, as a rule. The two arrangements of joints in most common use are as follows: (1) Suspended joints, with rail ends projecting beyond the shoulder ties and spliced by angle bars. In several cases these joints are stiffened by the use of bars having webs which extend below the rail. In few, if any, cases is the base of the rail now supported by a device fitted between the rail and the lower webs of the bars, but not resting upcn the ties. (2) Bridge joints, with rail ends projecting as above described, but resting upon bridge plates whose ends are supported on the shoulder ties. These plates are either independent of or integral with the splice bars. The Chicago & Northwestern Ry. has used independent bridge plates for several years. The Chicago, Rock Island & Pacific Ry. has recently adopted a similar arrangement as its standard, but has not yet applied it to any extent. There is a very general use of patented joints of various types, most of which have either a base support or a deep and stiff splice bar (extending below the rail) as the special feature. Some roads report that there is less work of maintenance required with rail joints of the bridge type as compared with those of the ordinary angle-bar type. Such a result would be reasonably expected. The Michigan Central Ry. is experimenting with several forms of rail joints, as shown below:

RAIL JOINTS; MICHIGAN CENTRAL RY.

Rail Wt. per Yd.	Type of Joint.	Susp. or Supp.	Bolts.* No.	Bolts.* Diam. and Length under Head	Spacing of Bolts.					Splice Bars. Length.	Splice Bars. Wt. per Pair.
lbs.				ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
100	38-in. angle bar	Supp.	6	1×5	8	6	4	6	8	38	95.8
100	25-in. angle bar	Susp.	4	1×5	..	7	4	7	..	25	64.8
100	100 per cent	Susp.	4	1×5	..	7	4	7	..	24	73.0
100	Wolhaupter	Bridge.	4	1×5	..	7	4	7	..	..	....
80	44-in. angle bar	Supp.	6	$\frac{3}{4}\times4\frac{1}{4}$	9	6	6	6	9	44	76.8
80	38-in. angle bar	Supp.	6	$\frac{7}{8}\times4\frac{1}{2}$	$7\frac{1}{2}$	6	6	6	$7\frac{1}{2}$	38	65.2
80	25-in. angle bar	Susp.	4	$\frac{7}{8}\times4\frac{1}{4}$	..	6	6	6	..	25	46.9
80	23-in. angle bar	Supp.	4	$\frac{7}{8}\times4\frac{1}{4}$	..	6	6	6	..	23	....
80	Continuous	Bridge.	4	$\frac{7}{8}\times4\frac{1}{4}$	..	6	6	6	..	25	62.9
80	100 per cent	Susp.	4	$\frac{3}{4}\times4\frac{1}{4}$	..	6	6	6	..	25	....

* All bolts have square heads.

The common spike, though inefficient for heavy track carrying heavy traffic is used almost universally. Sharp-pointed spikes are extensively used, but the practice of curving and grooving the spike to improve its hold in the tie has been given up, as affording little real advantage. Of 59 railways, only 8 are experimenting with improved fastenings. These fastenings are screw spikes in all cases, but the experiments are on a very limited scale. Bolts and clamps are occasionally used on bridges having steel decks. The bolted clamp fastenings used with steel ties are generally efficient in direct holding power, but appear to be deficient in ability to resist lateral thrust. In many cases the

bolt bears directly against the back of the bolt hole, and has consequently a small bearing area. In European practice the clamp (or a tie-plate) engages with the hole in the tie and gives an increased area of bearing for the bolt.

Figures as to the life and cost of ties are indefinite and unreliable, usually based upon guess work and vague averages. They indicate a decided stiffening of prices. Oak ranges from 60 to 90 cts. (27½ cts. on one road in Louisiana); cedar, 30 cts. to 70 cts.; pine, 45 to 90 cts.; chestnut, 45 to 65 cts. The quality also has doubtless deteriorated. The 8-ft. tie is in most extensive use, 35 railways using this, as against 19 using 8½-ft. ties. Only three report using 9-ft. ties, and this length is not standard, but used in special cases. It is coming to be realized that ties 6 ins. thick are not stiff or rigid enough for the heaviest class of traffic, and there is a general tendency to increase the thickness to 7 ins. Anything more than this is exceptional.

In width, the specified standard is generally 8 or 9 ins.; but narrower ties are used. The Duluth & Iron Range Ry. uses ties 6 to 10 ins. wide, but instead of a fixed number of ties per rail it specifies 130 linear inches of tie-bearing to a 30-ft. rail length. The Michigan Central Ry. is also considering the plan of making the number of ties per rail variable according to width of ties, so that in all cases the rail would be supported for a certain percentage of its length.

Treated ties are used to some extent by many of the railways, but in only a few cases have they been used in large numbers, or for a sufficient length of time to enable definite results to be stated. The economy of such ties when well treated and properly used has been amply proved. Their more general use as a regular feature of track construction rather than as an experiment is much to be desired.

The use of metal tie-plates is very general, but would be more effective if combined with the use of screw spikes instead of common spikes. The plates used most extensively are those having flanges or chisel points which enter the wood and make the plate practically an integral part of the tie. Some important railways, however, are reverting to the use of flat-bottom plates, or else plates in which the flanges are only large enough to prevent the plate from slipping on the face of the tie. Screw spikes are particularly desirable for these latter types of plates. The flat-top tie-plate and the tie-plate with a shoulder or rib on the top to fit against the outside edge of the rail base are used to about the same extent, but there is an evident tendency toward increased use of the shoulder plate. On most railways, the tie-plates are used mainly on curves and on soft ties; also for turnouts.

Ballast continues to be most variable in character, quality and quantity. The term "gravel" covers anything and everything from dirty bank gravel (full of sand or loam, or with a considerable proportion of large stones) to clean-washed and screened gravel, which is nearly as good as stone ballast. While the use of stone ballast is reported by many railways, it is very generally confined to comparatively short stretches of busy main track. The new Virginian Ry., however, is using stone throughout; this road is being built for a very heavy coal and freight traffic. The tendency is to use smaller sizes of broken stone than were used some years ago, the purpose of the change being to obtain a denser and more substantial bed of ballast. In some cases, screenings have been applied upon coarse stone ballast. The size of ballast is specified usually for a range of from ¾-in. to 2½-in., although some roads specify a single size (1½-in., 2-in. or 2½-in.). Slag does not seem to be used

except in the near vicinity of furnace plants, and burned clay appears to be going out of use. The depth of ballast under the ties on main track averages from 8 to 12 ins., but might in many cases be increased to advantage where heavy loads and traffic are carried. A combination is used in some few cases. Thus, on some parts of its line the Michigan Central Ry. uses 6 ins. of $1\frac{1}{2}$-in. stone on 6 ins. of gravel. The Lake Shore & Michigan Southern Ry. also uses 8 ins. of stone ($\frac{1}{2}$-in. to $1\frac{1}{2}$-in. in size) on 12 ins. of gravel or slag. For stone ballast, limestone is used in a majority of cases. Granite, trap and hard sandstone are also mentioned.

For turnouts, the bolted type of frog continues to be most generally used. Spring-rail frogs are usually adopted for main-line turnouts where the siding or turnout traffic is relatively small. The frogs for main track are usually Nos. 9 to 12, the higher numbers being for passing sidings. Rigid frogs of Nos. 15 to 20 are often used at junctions and the connections of double-track to single-track sections. For yard work, Nos. 7 to 9 are most commonly used. The Yards and Terminals Committee of the American Railway Engineering and Maintenance-of-Way Association formerly recommended No. 9, but has changed the recommendation to No. 8. The reason given was that the latter takes less room, turns a greater angle, costs less and is equally good from the point of view of yard service. The Pennsylvania Lines use No. 7, and the same is practically standard for all the classification yards around St. Louis. The No. 7 and No. 8 frogs put the leads closer together than where a No. 9 is used, and thus give a shorter distance for the cars to travel in switching. This is of importance in utilizing the available space and in operating the yard. However, No. 7 should be the minimum for yards of modern design.

In regard to the width of flangeway for frogs and guard rails, 38 railways continue to use $1\frac{3}{4}$ ins., while 18 use $1\frac{7}{8}$ ins. and three use 2 ins. The increase from the old standard of $1\frac{3}{4}$ ins. to $1\frac{7}{8}$ ins. is usually intended to provide for the latest wheel design of the Master Car Builders' Association. It has been shown, however, that the increase in thickness of wheel flange below the level of the rail head is very slight, and that the wheels can safely operate in the $1\frac{3}{4}$-in. flangeway. If any change is to be made, it should first be discussed by the rolling-stock department as well as the maintenance-of-way department, in order that both sides of the question may be given consideration.

The split switch is practically universal as a standard. A few roads continue to use special switches (with unbroken main-line rail) in certain cases, but the use of such devices does not appear to be on the increase. The stub switch is practically obsolete for main track and is rapidly disappearing from yards. For ordinary turnouts, the 15-ft. switch rail is almost universal, whether for 30-ft. or 33-ft. rails. A few roads using 33-ft. rails make the switch rail $16\frac{1}{2}$ ft. long, and others make the length 18 ft. or 20 ft. Switch rails 20 ft. to 30 ft. long are used in high-speed turnouts. In yards and on unimportant branches or industrial spurs, 10-ft. rails are sometimes used.

The automatic switch (with spring connection in the head rod of the switch) has almost disappeared, and where used it is confined to yards or branch lines. Automatic and rigid switchstands are used almost equally, but the latter is gradually superseding the former for main-track switches. In 1900, 24 railways reported the automatic and 23 reported the rigid switchstand as standard: in 1908 the numbers are 23 and 29 respectively.

There has been a marked increase in the use of distant signals to protect

main-track switches, aided no doubt by the numerous cases of derailment and collision caused by open switches having no other protection than a common target and lamp on the switchstand. The increase is partly accounted for by the extension of the block system and the use of interlocking plants. Apart from these, however, there is a marked tendency to apply distant signals in connection with ordinary outlying switches, especially where the view is obstructed or other dangerous conditions exist. In view of the increase in density and speed of traffic on many lines not operated on the block system, it is most desirable that a safety device of this kind should be more generally adopted as a protection for trains, pending the introduction of block signals.

Footguards should be used to prevent employees from getting their feet caught under the rail heads in the angles of frogs, the heels of switches and the ends of guard rails. There are numerous fatalities and injuries resulting from men being struck by trains while held in this way. The use of the guards is not so general as it should be, and some railways use them only in states where their use is compulsory. In many modern frogs, the raising block forms an effective footguard at the heel. An iron bar or heavy strap set on edge makes an efficient guard, being bent into a loop which is forced between the webs of the rails. Many railways prefer cast-iron blocks. Wood blocking is efficient when new, but is liable to become worn and damaged, and to be left neglected in that condition. The Hart footguards used by several important lines consist of wooden bars of triangular section fitted against the rail webs as fillers; the inclined face slopes from the bottom of the rail head to the edge of the rail base, thus effectively preventing a man's foot from being caught under the rail head.

Guard rails and transverse tie-rods or tie-bars on curves are for the purpose of preventing derailment, the former by guiding the wheels and the latter by holding the rails. The use of these devices is limited, and is confined mainly to sharp curves in yards. In view of the many derailments on curves, the stresses to which the spikes are subjected, and the difficulty and expense involved in maintaining gage on curves, it would seem desirable to place guard rails and tie-bars on main-track curves used by high-speed trains, thus relieving the outer rail of some of the lateral or "bursting" pressure. The tie-bar may be in two parts, each having one end bent up to engage the edge of the rail base. The inner ends are threaded and connected by a turnbuckle. The Michigan Central Ry. is considering the use of long plates (like the slide plates at switch points) extending under both rails. These would be for curves of over 30°, and it is thought that they would be preferable to tie-rods passed through the webs of the rails, such as are used in street-railway track.

Guard rails are, of course, generally used on bridges; they are used sometimes on high embankments, where derailments would be disastrous unless the guards were provided to keep trains from going over the bank. It is strange, however, that many railways in building concrete bridges lay the track level with (or even above) the coping, but omit to provide any guard rails. The idea seems to be that such protection is needed only on the open floors of trestles or steel bridges, and not where the regular track construction is carried across a structure. A derailment when crossing (or approaching) a concrete bridge under the conditions noted above would be very liable to result in a serious accident.

Reviewing the situation as a whole, it may be said that the tables show the

present standards of track construction to be good as far as they go; but it has been pointed out already that they have not yet been applied universally even where fast and heavy traffic is imposed upon the track. In too many cases the actual track construction (whether "standard" or not) is far from being consistent with or in proper relation to the loads and work imposed upon it.

TABLES OF STANDARD TRACK CONSTRUCTION ON AMERICAN RAILWAYS (APPENDIX).

Table I.—Rails and Rail Joints.
Table II.—Ties and Tie-plates.
Table III.—Frogs, Switches, Switchstands, and Turnouts.
Table IV.—Rail Fastenings, Ballast, Guard Rails on Curves, Tie-rods for Curves

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57 Virginia
58 Wabash
59 Wiscons

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